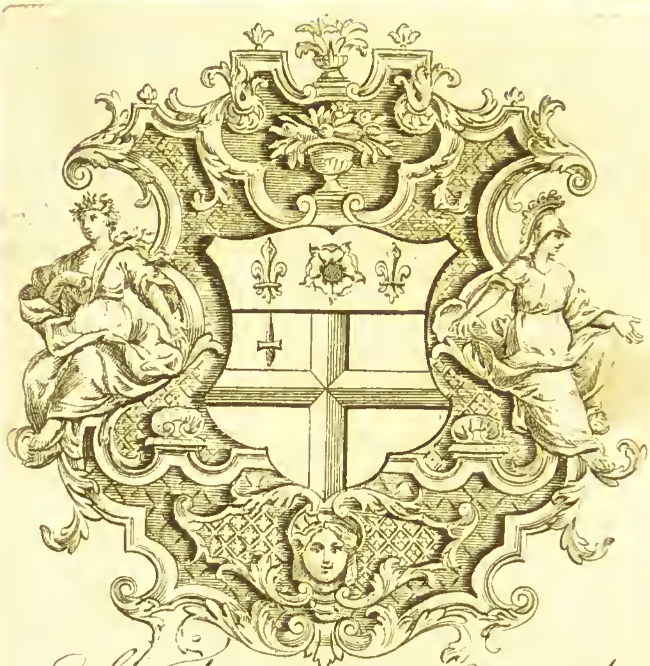

OUTLINES

OF

HUMAN PHYSIOLOGY.

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FOURTH EDITION.

LONDON:
HENRY RENSHAW, 356, STRAND,
AND
J. CHURCHILL, PRINCES STREET, SOHO.
1837.

PREFACE

TO

THE FOURTH EDITION.

The present Edition of this work has been increased by upwards of an hundred pages of the type used in the last. The additions are dispersed through the volume, the whole of which has been carefully revised: but the reader will find the principal in Chapter V, Section 2, where Mr. Kiernan's discoveries in the anatomy of the liver are described—in Chapter VIII, where M. Breschet's researches upon the structure of the skin are noticed—in Chapter IX, Section 1, under the head of somnambulism; Section 3, in which the anatomy of the brain is explained; Section 5, in which the relation of the size and figure of the brain to mental development is examined—in Chapter X, on the organs of the senses—in Chapter XI, on voluntary motion—in Chapter XII, Sections 2 and 3, on the vascular connection between the fœtal and maternal systems—in

Chapter XIII, on the proximate cause of inflammation—in the Appendix, in which are given, an analysis of Dr. Addison's and Mr. Morgan's researches upon the absorption of poisons, the results of Dr. Beaumont's inspection of the stomach in the case of Alexis St. Martin, the observations of Weber on the sense of touch, and an account of Professor Ehrenberg's discovery of the tubular structure of the brain and nerves.

The evidence, by which the functions of organs are determined, is partly taken from the phenomena of disease; to throw light upon the causes, and prevention, and treatment of which, constitutes on the other hand the practical application of physiology. Accordingly, in the present volume the reader will find several subjects entered into, which are elements in the history of disordered bodily actions. For a further investigation of them, he is referred to the Author's Outlines of Pathology.

The greater part of an elementary treatise is necessarily compiled of the knowledge of others, of facts and conclusions, which have been progressively accumulating, since science began. If the treatise is compendious, the original contributions of the Author require to be stated concisely, like the rest, and are therefore not easily found by readers, who have occasion to refer to them. On this account, the following index has been inserted

of the principal physiological observations in the present volume, for which the Author is responsible.

Page

Detection of a part analogous to a sentient organ in the mimosa pudica 13

Experiment to prove that a muscle, in contracting, gains in breadth exactly what it loses in length.. 32

Characteristics of voluntary and involuntary muscles..................37—39

Explanation of the action of the mitral valve 43

Experimental evidence relating to the source of the heart's action ... 46

Experiment to cause an artery partially to dilate 51

Tortuousness of arteries, in parts, where there is, or has been, local action, explained; and elucidated by experiment. Nature of local action explained.. 52—54

Use of the circumflexus palati; observed in cases of congenital fissure of the soft palate.. 95

Analysis of Instinct ....171—175

Analysis of Belief ....181—184

Experiment to show the independence of the optic tubercles, conjointly with the second and third nerves, of the rest of the enkephalon; and conclusion from the fact 212

White matter of the spinal cord, its structure as displayed after maceration in alcohol: the spinal cord partly dependent, and for transmission; partly independent, and capable of originating impulses, like the tubercles, and the intervening tract ....213—216

Measurement of the proportions of the anterior and posterior fasciculi of the cord at different parts. Difference of figure of the grey matter in different parts of the cord; and reason..................216, 217

Explanation of the phenomena of hemiplegia, when caused by partial cerebral lesion..222—224

Refutation of Dr. Foville's theory of the anatomical relations of the corpus callosum 235

Reasoning and experiments, by which it was proved that the hard portion of the seventh nerve is the exclusive motor nerve of the muscles of the face; and that the facial branches of the fifth nerve are exclusively sentient..252—256

The sympathetic nerve not only gives branches to the sixth cerebral and to the spinal nerves, but likewise receives branches from them 261

Page

Structure, in the human head, of the commissura tractuum opticorum represented, page 262:—described 295

Law determining the places of origin of nerves 262

Experiment of pressure on the eye-ball to illustrate the law of visual direction 274

Researches on the motion of the iris ....286—292

Reasons to account for the distribution of three motor nerves to the muscles within the orbit ....298—300

Refutation of Panizza's experiments upon the nerves of the tongue; and experimental and analogical proof of their true uses ......314—318

Remarks upon impressions of direction and motion; of equilibrium; hypothesis maintained of the dependence of sea-sickness upon the sense of disturbed equilibrium........ ....322—329

Facts showing the position of the laryngeal ligaments common to vocalization and closure of the glottis 371

How we judge of the direction in which a person or a portrait is looking. Dr. Wollaston's hypothesis controverted 357

Shape and size of the particles in pus determined, and some othe phenomena of inflammation elucidated...............................471—476

Common principle in the reunion of bones, cartilages, tendons, nerves ....477—490

19, George Street, Hanover Square,

January 1, 1837.

CONTENTS.

CHAPTER I.

OF LIFE AND ORGANIZATION.

	Page
Organized Bodies are Plants and Animals	1
Functions of Unorganized Bodies	2
Meaning of the Term Life	2
General Differences between Organized and Unorganized Matter	3
General Anatomy, what	3
Special Anatomy, what	4
Proximate Principles of Animal Matter	4
Ultimate Elements	5
Decomposition of Animal Matter	5
Antiseptic Agents	6
Vital Phenomena common to Plants and Animals	7
Growth	8
Generation	9
Properties of Life:—	
Vital Affinity	9
Irritability	10
Sensible Motions of the Mimosa Pudica	11
Discrimination shown in the Growth of Plants	14
Animal Life	16

CHAPTER II.

OF THE BLOOD.

First Appearance of Circulating Organs	17
Theory of the Circulation of the Blood	19
Proofs adduced by Harvey	21
Difference of Arterial and Venous Blood	21
Coagulation of the Blood	22
Separation of the Coagulum into Serum and Crassamentum	23
Serum of the Blood	23
Fibrin of the Blood	23
Coloured Particles	24
Circumstances which retard Coagulation	25
prevent Coagulation	26
Final Causes of the Coagulation of the Blood	27

CHAPTER III.

OF MUSCULAR ACTION.

Page
Parts which possess Irritability specified ... 28
Structure of Muscular Flesh ... 29
Dr. Hodgkin and Mr. Lister's Microscopic Observations ... 30
Nerves of Muscles ... 30
State of a Muscle, when Relaxed ... 31
when Contracted ... 32
Change in the Disposition of the Fibres of a Muscle when in Action ... 33
Tone of Muscles ... 34
Rigidity of Muscles after Death ... 35
Distribution of Muscles in two Classes, Voluntary and Involuntary ... 37

CHAPTER IV.

OF THE CIRCULATION OF THE BLOOD.

§ I.

OF THE MECHANISM OF THE CIRCULATION.

General Agency of the Heart ... 40
Use of the Aortic and Mitral Valves ... 42
Of the Sounds of the Heart ... 44
Computed Force of the Left Ventricle ... 45
Source of the Heart's Action ... 46
Influence of the Brain and Spinal Cord over the Heart ... 47
Frequency of the Heart's Action ... 48
Momentum of the Blood in the Veins ... 48
Structure of an Artery ... 48
of a Vein ... 49
Ratio of the Capacities of Arteries and Veins ... 49
Properties of the Capillaries ... 50
Pulsation of Arteries ... 50
Proof of the Irritability of Arteries ... 51
Mechanism of Local Action ... 52
Permanent Inequalities of the Circulation ... 54
Veins thicker in the Lower Extremities ... 54
Cerebral Arteries tortuous at their Entrance into the Skull ... 55
Influence of Breathing on the Circulation ... 56

§ II.

OF THE PULMONARY CIRCULATION.

Structure of the Lungs ... 57
Mechanism of Respiration ... 58
Average Quantity of Air inspired and expired ... 60
Extreme Quantities ... 61
Changes produced in the Air by Breathing ... 61

Page
Gaseous Mixtures that are Respirable 64
Gases that are Noxious or Irrespirable 65
Halitus of the Breath 66
Pulmonary Absorption 66
Consent between Respiration and the Action of the Heart 66
Influence of the Nerves in Breathing 67

§ III.

OF THE SYSTEMIC CIRCULATION.

Agency of Arterial Blood in sustaining Vitality 68
Of Syncope 69
Of Transfusion of Blood 69
Of Asphyxia 70
Effects of Nitrous Oxide 70
Introduction of Water and of Medicines into the Blood 71
Of Nutritive Secretion 73
Influence of the Nerves in this Function 74
Law which regulates it 74
Of Functional Secretion 75
Different Organs of Functional Secretion 76
Influence of the Nerves 76
Relation of Functional Secretions to the Blood 77
Origin of Animal Heat 78
Crawford's Hypothesis 78
Sir Benjamin Brodie's Experiments 78
Dr. Wilson Philip's Experiments 79
Sir Everard Home's Experiments on the Temperature of the Growing Antler 79
Imbibition by Blood Vessels 80

CHAPTER V.

OF DIGESTION.

§ I.

OF HUNGER AND THIRST; OF THE MASTICATION OF FOOD, AND OF DEGLUTITION.

Seat of Hunger and Thirst 86
Description of the Fauces 87
Structure of the Teeth 88
Their Number, Place, Uses 89
Motions of the Lower Jaw 90
Of the Muscles of the Tongue 91
Of the Salivary Glands 92
Quantity of the Saliva 93
Of the Soft Palate 94
Of Deglutition 95

§ II.

OF THE ALIMENTARY CANAL FROM THE ŒSOPHAGUS DOWNWARDS, AND OF THE FLESHY VISCERA CONNECTED WITH IT.

	Page
Coats of the Alimentary Canal	97
Irritability of the Muscular Coat	99
Triple Division of the Alimentary Canal	99
Of the Stomach, its Shape, Situation, Glands	101
Of the Nature and Properties of the Gastric Secretion	101
Three Modes in which the Stomach is emptied	103
Mechanism of Vomiting	104
Of the Pylorus	104
Structure of the Small Intestines	105
their Glands, Villi, Valvulæ Conniventes	105
Of the Great Intestines	106
Of the Spleen	107
Of the Pancreas	108
Of the Liver	108
Mr. Kiernan's Discoveries	108
Nature of the Bile	113

§ III.

OF THE FUNCTION OF THE STOMACH.

Commencement of Digestion	116
Formation of Chyme	117
Air and Water, how disposed of	116
Chemical Action of the Secretions of the Stomach on the Food	118
Observations of Tiedemann and Gmelin	119
Dr. Prout's View of the Agency of the Stomach	119
Period necessary for Chymification	121
Influence of the Nerves of the Stomach	121

§ IV.

OF THE FORMATION OF CHYLE.

Influence of the Bile and Pancreatic Secretion on the Chyme	124
Researches of Tiedemann and Gmelin	126
of Leuret and Lassaigne	126

§ V.

OFFICE OF THE GREAT INTESTINE.

Analysis of the Contents of the Cæcum	131
of the Colon	133
of the Rectum	134

§ VI.

OF THE VARIOUS SUBSTANCES EMPLOYED AS FOOD.

Degrees of Nutriment which different Substances afford	136
Dr. Prout on the Elements of Nutriment	137
Use of Variety in Food	138

CHAPTER VI.

OF THE LACTEAL AND LYMPHATIC VESSELS.

Page

Anatomy of this System 141
Researches of Lippi 143
Nature of Chyle 144
Nature of Lymph 144
Tiedemann and Gmelin on Chyle and Lymph 145
Origin of the Lacteals 146
Fallacies in the Experiments of Mr. Hunter on Lacteal Absorption explained 148
Three Forms of Absorption now distinguishable 150

CHAPTER VII.

OF THE URINARY ORGANS.

Anatomical Description 152
Composition of the Urine 154
Mode of Irritability possessed by the Bladder 155
Rapidity with which Substances swallowed reach the Urine 156
Effects of removing the Kidneys 157

CHAPTER VIII.

OF THE SKIN.

Functions of the Skin quintuple 158
M. Breschet's account of its Structure 159
Isolation effected by the Epidermis 161
Cutaneous Absorption 161
Cutaneous Secretion 162
Its influence on Animal Heat 163
Phenomena of Hybernation 164
Death from extreme Heat 166
Sir Charles Blagden's Experiments 167

CHAPTER IX.

OF THE FUNCTIONS OF THE NERVOUS SYSTEM.

§ I.

OF THE MENTAL PHENOMENA IN MAN AND ANIMALS.

Of Sensation and Perception 169
Early Perfectness of the Sensations of Animals 170
Of Volition 171
Of Instinct 171
Instinctive Actions voluntary 172
Sir Charles Bell's Theory 173
Of Modified Instincts 175

	Page
Of Conception as displayed by Animals	176
Of Memory	177
Of Imitation	177
Of Discriminative Observation	177
Have Animals reason?	178
Professor Glennie's account of James Mitchell	179
Of Attention	181
Of Belief	181
Of Intuitive Truth	181
Of Syllogistic, Inductive, and Mathematical Truths	183
Of Belief upon Experience and Analogy	184
Of Cumulative Proof	184
Deductions as to our Being, our Duties, and Expectations of a Future Existence	185
Of the Moral Sense	186
Of Taste	186
Of Talent	186
Of Arithmetical Talent	187
Of Disposition	187
Of the Active Principles of Man	188
Nature of the Mind	188
Of Sleep	188
State of the Body	189
State of the Mind	189
Influence of Volition not suspended	191
Of Somnambulism	193
Of Double Consciousness	195
Of Spectral Illusions	196
Case of Nicolai	197
Of Mental Failure and Decay	201

§ II.

OF THE ELEMENTS OF A NERVOUS SYSTEM.

Materials of the Nervous System	203
Two Parts always	204
Central Organ of the Nervous System :—	
in Radiated Animals	205
in Articulated Animals	205
in Mollusca	206
in Vertebral Animals	207
Characteristic Features of the Central Organs in Vertebrals	208
Different Functions of the Brain and of the Cord	210
Part on which Vitality depends	211
Degree of Independence in each Part	212

§ III.

OF THE SPINAL CORD.

The Spinal Cord an Agent of Transmission	213
an Originator	214

Page

The Spinal Cord consisting of Independent Segments 214
Of their Mutual Influence 215
External Markings of the Spinal Cord 215
Length and Thickness of the Cord 216
Arrangement of White and Grey Matter 216
Differences at different Parts, and their Rationale 217

§ IV.

OF THE ENKEPHALON.

Of the Medulla Oblongata 217
Its Figure and Eminences 218
Part immediately Vital 219
Relation of, to Nerves 219
Communication of its Parts with the Brain and Spinal Marrow 220
Of the Course and Decussation of the Anterior Pyramid 220
Phenomena of Hemiplegia explained 222
Of the Cerebellum 224
Description of the Method of Examination employed by Professor Reil... 225
Structure of the Cerebellum as so displayed 227
Experiments of Fodéra and Magendie on the Cerebellum 229
Experiments on the Pons Varolii 230
Of the Cerebral Tubercles 231
Experiments of Magendie 231
Of the Cerebrum :—
Structure analogous to that of the Cerebellum 233
Dr. Foville's Views controverted 235
Experiments of Magendie 235
Of the Water in the Ventricles 237

§ V.

OF THE RELATION OF THE MAGNITUDE AND FIGURE OF THE ENKEPHALON TO MENTAL DEVELOPMENT.

Influence of Magnitude 239
Influence of difference of Structure: wherein the Superiority of the Brain of one Animal over that of another consists 240
Wherein the Superiority of one Human Brain over another 242
Of the Phrenological Theory : —
Observations of Tiedemann on the Size of the Brains of different Nations 245

§ VI.

OF THE FUNCTIONS OF THE NERVES.

Of the Spinal Nerves 248
Original Views of Sir Charles Bell 249
Magendie's Experiments 249
Of the First and Second Cerebral Nerves, and of the Soft Portion of the Seventh 250

Page
Of the Third, Fourth, Sixth, and Ninth Cerebral Nerves 251
Of the Fifth Nerve, and of the Hard Portion of the Seventh 251
Sir Charles Bell's Experiments 252
Experiments by the Author.. 254
Views entertained by Bellingeri.. 256
Of the Glosso-pharyngeal Nerve, the Pneumo-gastric, and the Spinal Accessory 257
Of the Sympathetic 258
Its connection with the Cerebral Nerves................................ 260
Law of the Place of Origin of Sentient and Motor Nerves 263

§ VII.

INFLUENCE OF THE NERVES ON THE VEGETATIVE FUNCTIONS.

On Involuntary Motion 265
On Secretion... 265
Looping or Anastomosis of Nerves....................................... 265
On Nutrition... 266

CHAPTER X.

OF THE ORGANS OF THE SENSES.

Senses distinguished into Internal and External........................ 268
Of the Inward Senses 268
Arrangement of the External Senses..................................... 269

§ I.

OF THE ORGAN OF VISION.

Of the Retina 270
Of Light 270
Of Colour 271
Of Complementary Colours... 271
Of Defective Vision of Colours 272
Perception of the Blood-Vessels of the Retina 273
Of Visible Figure 274
Of the Law of Visual Direction... 274
Use of the Inversion of the Picture on the Eye......................... 277
Of Myopic Eyes 277
Of Presbyopic Eyes... 277
Schneider's Experiments.. 278
Refractive Power of the Cornea... 279
of the Aqueous Humour 279
of the Crystalline 280
of the Vitreous 280
The Eye Achromatic 280
Of the Knowledge directly obtained by Vision............................ 281
Cheselden's Case 281
Of Visual Distance 282
Of Visual Magnitude 283
Of Single Vision with Two Eyes 283

	Page
Of Double Vision	283
Mr. Wheatstone's Observations on Binocular Perspective	285
Use of the Chorioïd	285
Of the Eye of the Albino	285
Use of the Iris	286
Mechanism of the Motions of the Pupil	287
State of the Pupil in Death	288
Alteration of the Focal Length of the Eye	289
Acquired Power of moving the Iris	292
Extent of the Field of Vision	293
Mariotte's Experiment	294
Partial Anæsthesia of the Retina	295
Of the Sclerotic	297
Of the Muscles of the Eye	298
Theory of their Uses	299
Of Squinting	300
Of the Lachrymal Gland and Eyelids	301

§ II.

OF THE ORGAN OF HEARING.

Of Sound	303
Limits of Audition	304
of Musical Pitch	304
Velocity of Sound	305
Diffusion of Sound	305
Of the Organ of Hearing	305
Of the Labyrinth	306
Of the Vestibule	306
Of the External Ear	307

§ III.

OF THE SENSE OF SMELL.

Of Odours	308
Of the Organ of Smell	309
Experiments of Magendie	310
Case proving the First Nerve to be the Olfactory	311

§ IV.

OF TASTE.

Organs of Taste	312
Of the Papillæ of the Tongue	312
Of the Soft Palate	312
Sensations excitable in the Fauces	313
Separate Offices of the Nerves of the Tongue	314
Examination of the Experiments of Panizza	315

§ V.

OF THE SENSE OF EFFORT.

Page
Nature of Sensations of Effort 319
Nerves on which they depend 319

§ VI.

OF THE SENSE OF TOUCH.

Nature and Organ 320

§ VII.

OF SENSATIONS OF HEAT AND COLD.

Organs of these Sensations 321
Influence of Custom upon them 321

§ VIII.

OF THE SENSE OF MOTION.

Nature and Seat of Sensation of Motion 322

§ IX.

ON SOME OF THE USES OF SENSATION.

Use of Sensation in steadying the Mind 322
Impressions of Locality conveyed by Sensation 323
Impressions of Outness 323
Impressions of Direction 323
Use of Sensation in Voluntary Motion 324
Use of Sensation in maintaining Equilibrium 325
Giddiness and Sickness how produced 326
Observation of Direction displayed by Animals 328

CHAPTER XI.

OF VOLUNTARY MOTION.

§ I.

OF THE BONES AND JOINTS.

Importance of Osteology 331
Bones of Three Kinds: their Uses 333
Composition of Bone 334
Joints of Three Kinds 335
Of the Joints of the Spine and Pelvis 336
Of Joints with Discontinuity 336
Of Synovial Membranes and Synovia 336
Of the Analogical Design in the Skeleton 337
Of the fitness of the Skeleton for the Erect Posture and Erect Progression 339
Of the Strength of the Skeleton 340
Of the Arterial Canal in the Cervical Vertebræ 341

Page
Of the Elbow Joint 342
Of the Knee Joint 342
Of the Hip Joint 343

§ II.

OF THE VOLUNTARY MUSCLES AND THEIR TENDONS.

Disposition of Voluntary Muscles 344
Their Attachments 344
Of Tendons 345
Use of Tendons 345
Of Straight and Pennated Muscles 346
Tendons on opposite Surfaces of Muscles 347
Of Antagonist Muscles 348
Of Vestiges 348
Different Applications of the Principle of the Lever in the Human Frame 349
Of the Strength of Muscles 349

§ III.

OF THE ATTITUDES AND MOVEMENTS OF MAN.

Of the Support of the Body in a given Position 350
Of Walking 351
Of Leaping 352
Of Swimming 354

§ IV.

OF PHYSIOGNOMICAL EXPRESSION.

Two Principles in Action 355
Expression of the Bodily Frame 356
Expression of the Countenance 357
Of interpreting Physiognomy 357
Fallacies 357
How we judge that a person or portrait looks at us 357

§ V.

OF THE MECHANISM OF BREATHING.

Of the Thorax 358
Its Increase or Diminution in Depth 358
in Breadth 359
in Height 360

§ VI.

OF THE MECHANISM OF SPEECH.

Of Instruments to produce continued Sound 361
Of the Syren 361

Page
Of the Strings of a Harp or Violin 362
Of a Tube of Grass or Indian Rubber 363
Of the Lips 363
Of the parts of which the Vocal Organs consist 364
Mr. Willis's Table of the Action of the Laryngeal Muscles 368
Mr. Willis's Hypothesis of the Production of Vocal Sounds 369
Facts observed in a Case where the Larynx was laid open 371
Hypothesis grounded on these and on other Observations 370
Theory of Savart 373
Influence of the Trachea 373
Mr. Richmond's Musical Performance 374
Of the Falsetto Voice 375
Mr. Willis's and Mr. Wheatstone's Explanations 375
Range of the Human Voice 375
Of Articulate Speech 375
Of the Vowel Sounds 375
Mr. Willis's Explanation of their nature 376
Change in the Position of the Lips and Fauces requisite to produce them . 376
Mr. Wheatstone's Arrangement of the Consonantal Sounds 377
Positions of the Tongue and Fauces necessary for their formation 378
Softening of Modern Languages derived from the Latin 379
Of Stammering 379
Of Speech during Inspiration 380
Of Coughing, Hiccuping, Sneezing 380
Of Laughter and Snoring 380
Use of the Larynx to protect the Lungs 380
The inferior Laryngeal Nerves why recurrent 381
Means of Closing the Glottis 382
Occasions in which this is hurtful, Hydrophobia 383
Occasions in which it is necessary 384

CHAPTER XII.

OF GENERATION.

Of Equivocal Generation 385
Various Modes of Reproduction 385

§ I.

OF IMPREGNATION.

Of the Ovaries, Uterus, Vagina 386
Of the Testes and Seminal Secretion and of Puberty 387
Discovery of the Ovulum by Baer 393
Structure of the Graaffian Vesicle 394
Of Corpora Lutea 395
Conditions necessary to Impregnation 395
Place in which the Ovum is fertilized 396

Page
Influence of the Male on immature Ova 397
Of Twins 398

§ II.

OF THE DEVELOPMENT OF THE EMBRYO.

Appearance of the Ovulum in the Fallopian Tube 398
in the Uterus 399
Analogons appearance in the Egg 400
Of the Cicatricula 400
Of the Primitive Trace 401
Division of the Germinal Membrane into three Layers 401
Folding of the three Layers 401
Of the Vascular Area 403
Of the Vascular Area in the Conceptions of Mammalia 404
Development of the Serous Layer 405
Formation of the Spinal Cord and Medulla Oblongata 406
of the Cerebellum 408
of the Tubercles 408
of the Cerebrum 409
of the Nerves 410
of the Muscles 411
of the Organs of the Senses 411
of the Bones 414
of the Integuments 417
of the Limbs 418
Disproportionate growth of the Lower Limbs 419
Formation of the Amnios 419
Development of the Mucous Layer 420
Origin of the Alimentary Canal 421
of the Umbilical Vesicle 421
of the Mouth 422
of the Stomach 422
of the Small and Great Intestines 423
of the Salivary Glands 423
of the Liver 424
of the Lungs 425
of the Wolffian Bodies 426
of the Kidneys and Renal Capsules 427
of the Spleen 428
of the Thymus 429
of the Mammæ 429
of the Bladder and Urethra 429
of the Testes 429
of the Ovaries 430
of the Vascular Layer 432
of the Vascular Area 432

Page
Origin of the Heart 432
of the Systemic and Hepatic Circulation 432
of the Branchial Branches of the Aorta 432
of the Conversion of the Single into a Double Heart 434
of the Division of the Single Artery into Pulmonary and Aortic . 437
of the Fœtal Circulation 438
of the Formation of the Allantoïs 441
of the Navel-string and Amnios 443
of the Chorion 443

§ III.

OF THE NUTRITION OF THE EMBRYO, AND OF THE CONNECTION OF THE MATERNAL AND FŒTAL SYSTEMS.

Adaptation of the Chorion to the Mucous Membrane of the Uterus in Animals generally 444
The Cotyledonous form 445
The Preparation in Human Beings visible before the Third Month for a different Structure 446
That Structure the Placenta 447
Decidua Vera and Reflexa 449
Examination of Specimens in the Hunterian Museum in London, corroborating the Account of the Placenta given by Dr. William Hunter ... 450
Relation of the Placental Formation to the Catamenial Secretion. 453
Of Fœtal Digestion 454
Period of Utero-gestation 455
Of Labour 457
Of the Nutrition of the Infant after Birth 458

CHAPTER XIII.

OF GROWTH AND REPARATION.

Of the Growth of Teeth 460
Influence of the Nerves in this instance 461
Formation of the Milk Teeth 461
Order of their Appearance 462
Of the Permanent Teeth 463
Order of their Appearance 463
Life of Teeth 463
The Alveolar Processes 464
Formation of the Epidermis 464
Structure of the Horns and Hoofs of Animals 464
Epidermis of the Ostrich's Gizzard 465
Of the Structure and Growth of the Nails 465
Of the Structure and Growth of Hair 466
Of the Subcutaneous Adipose Tissue 468

Page
Of the Reparation of Soft and Vascular Parts 469
Of Union by Adhesion 469
Of Inflammation and its Consequences 471
Of Union by Callus 476

CHAPTER XIV.

OF THE VARIETIES OF THE HUMAN SPECIES.

Of Differences in the Colour of the Skin, and in the Texture of the Hair . 485
Of the Principal Differences in the Shape of the Head 487
Of the Steno-bregmate Cranium 487
Of the Meso-bregmate Cranium 487
Of the Platy-bregmate Cranium 487
Of the Diversities and Diffusion of the Æthiopian Race 490
of the Caucasian Race 497
of the Mongolian Race 501
Of the Hyperborean Race 507
Of the extinct Peruvian Race 508

APPENDIX........ 509

ERRATA.

Page 97, Line 26, *for* one fifteenth *read* one fiftieth.
111, ... 28, ... in ...... on.
111, ... 39, *dele* which takes from it.
223, ... 20, *after* hemiplegia *read* of the face.
257, ... 35, *for* tantum ...... tactum.
268, ... 1, ... Chapter IX ..... Chapter X.
269, ... 1, ... planes ...... plane.
269, ... 1, ... arranged ...... organized.
320, ... 15, ... is an organ ...... are organs.
343, ... 16, ... inwards, ... forwards.
343, ... 18, ... outwards ...... backwards.
344, ... 1, ... outwards ...... inwards.
370, ... 18, *before* have ...... may.
374, ... 40, *for* acquire ..... require.
384, ... 20, *before* higher ...... ascend.
444, ... 7, *for* $\frac{2}{7}$ area ...... $\frac{2}{7}$ diameter.
444, ... 8, ... Valpeau ..... Velpeau.
444, ... 8, ... corpus reticuli or vitri *read* reticulé or vitré.

" In the study of anatomy, every man proceeds on the maxim, that nothing in the body of an animal was made in vain ; and when he meets with a part of which the use is not obvious, he feels himself dissatisfied, till he discovers some at least of the purposes, to which it is subservient. ' I remember (says Mr. Boyle) that, when I asked our famous Harvey what were the things that induced him to think of a circulation of the blood ? he answered me, that when he took notice, that the valves in the veins of so many parts of the body were so placed, that they gave a free passage to the blood towards the heart, but opposed the passage of the venal blood the contrary way ; he was incited to imagine, that so provident a cause as Nature had not placed so many valves without design ; and no design seemed more probable, than that, since the blood could not well, because of the interposing valves, be sent by the veins to the limbs, it should be sent through the arteries, and return through the veins, whose valves did not oppose its course that way.' "

STEWART'S OUTLINES OF MORAL PHILOSOPHY.

OUTLINES

OF

HUMAN PHYSIOLOGY.

CHAPTER I.

OF LIFE AND ORGANIZATION.

The globe of the earth is formed of what are termed mineral substances, existing either in a solid, or in a liquid, or in a gaseous form. Upon or near its surface are found other bodies, which either live, or, being dead, preserve some remains of that shape and structure which they possessed during life. Living bodies are either plants or animals. The varied and elaborate mechanism calculated to perform determinate functions, which admits of being displayed in the greater number, has obtained for the whole the common appellation of organized bodies. Mineral substances, on the other hand, which taken individually consist of mere aggregations of similar particles, are termed unorganized.

Mineral bodies, as contrasted with living organized bodies, have been termed inert. Yet every mineral substance has properties, some common to all matter, others peculiar to itself, through which it becomes an important agent in Nature. The properties of inorganic matter are constantly operating to promote or counteract change. The surface of the earth is perpetually undergoing alteration through chemical or mechanical action. The atmosphere uniformly maintains the same chemical composition, borrowing from some unknown source to compensate for the perpetual abstraction of one of its constituents. The waters, which are constantly polluted through

their mixture with decaying animal and vegetable matter, are perpetually renovated by a very elaborate process. The vapors which rise from land and sea, are the element restored to a pure state by spontaneous distillation: the purified element being recondensed falls in rain, or hail, or snow, and becoming impregnated with atmospheric air, is again distributed over the earth, to diffuse fertility and health; a succession of phenomena, that are remarkable from the analogy which they bear to the functions of respiration and of the circulation of the blood in animals. The properties of unorganized matter again determine the alternations of night and day, the recurrence of the seasons, the motions of the planetary and sidereal systems;—a series of changes which may be termed the Life of the World.

In the preceding illustration of its meaning, the term Life is employed figuratively. In its direct sense it denotes other changes, which occur exclusively in organized bodies. It is important, however, to bear in mind, that the logical force of the term is the same in both instances: in its direct as well as in its figurative application, the word life is no more than a collective expression for a series of phenomena.

The aim of natural philosophy is to ascertain the causes of the phenomena of the universe. As soon as by observation and experiment the conditions have been determined, under which given classes of phenomena manifest themselves, the physical cause of such phenomena, or the *law* which regulates them, is said to be discovered; and some general expression is made use of, which strictly indeed denotes no more than the invariableness of the sequence of events, however it may figuratively appear to attribute causation to matter or to mind. The terms *property* and *principle* are commonly considered in natural philosophy equivalent to the term already used: yet each has its peculiar shade of meaning, fitting it to convey a different relation of the same idea. The word law serves to express the conditions essential to a change: the word property attributes to a substance the power of producing a change under ascertained conditions; while the word principle, characteristic of a less advanced state of science, has been generally employed (as the final letters of the alphabet are used by algebraists) to denote an unknown element, which when thus expressed is more conveniently analyzed. Consistently with the explana-

tion given, we state as the law of gravity the ratio in which masses of matter are reciprocally attracted; or we observe that masses of matter possess a property of reciprocal attraction; or we speak of the principle of electricity, or of the principle of magnetism, as the unknown causes of certain phenomena that are as yet imperfectly understood. Hitherto the laws of life, or the properties of living matter, have not been determined with precision; and physiologists have shown themselves reluctant to disuse the vague term, "a Principle of Life," to which an imaginary and delusive meaning is attached by many, who forget that terms of this nature have no real value, exept as generalized expressions of facts.

Organized bodies are distinguished from mineral substances, not less by their physical character, than by exclusively exhibiting the phenomena of life. Animals and plants are distributed in species, each of which has a limited bulk and peculiar form. Mineral substances on the contrary have no limit assigned to their magnitude or variety of figure. The former are generally composed of dissimilar parts, the latter are homogeneous. The former have in most instances curvilinear surfaces; the latter are commonly bounded by right lines. The former, which consist of materials produced in the laboratory of the living body by delicate combinations of mineral elements, are preserved from decomposition by the vital influence alone; and as soon as life has ceased, slowly or rapidly revert to the condition of inert matter. The latter, which derive their character from causes of more permanent operation, have less tendency to change.

Or the study of organized bodies embraces two inquiries, one of which regards their structure and composition, the other their powers and actions.

The structure of animals and plants is taught in anatomy, which shows, first, of what tissues or textures the organized body is wrought; this is GENERAL ANATOMY: secondly, how these tissues are combined to form different organs, and how those organs are disposed in reference to each other; this is SPECIAL ANATOMY.

The ELEMENTARY TISSUES of the human body have been classified with more or less neatness by various modern writers. The idea of such a classification originated in observing that there are several tissues which are common to, or with slight

modifications are employed in the construction of, different parts. Carmichael Smyth and Bordeu were the first to compare these common textures. Bichat, with philosophic brilliancy endeavoured to systematize the structural elements of the entire frame. Such generalizations are extremely useful: but the student in pursuing them must remember, that Nature, who made systems, is herself unfettered by system: that the analogical design and uniformity of means which she continually employs, are at once deviated from, and new elements introduced, for a single occasion even (as in the formation of the cornea or the crystalline), when her work would be bettered by the innovation.

The ORGANS of the human body are, the bones and joints, the muscles and tendons, the brain, nerves, and organs of the senses, the digestive apparatus, the lacteals and lymphatics, the heart and blood vessels, the respiratory organs, the urino-genital system.

The composition of organized bodies is taught by chemistry; which shows, first, of what materials the constituent tissues are immediately wrought; secondly, to what ultimate elements these materials may be reduced. The first are termed PROXIMATE PRINCIPLES.

These may for the most part be obtained by very simple processes. If a ductile paste is formed by the gradual addition of water to flour; and the paste is kneaded by the hand and washed by a slender stream of water, it becomes a grey, tenacious, and highly elastic substance, termed gluten. The water employed in the process is rendered turbid and milky; a white matter remains suspended in it, which is starch. When meat has been boiled in water, oil is observed to separate and float upon the surface: another substance extracted from the meat is dissolved in the water; this substance, which gellies on cooling, is gelatin: the tasteless shreds which remain are fibrin. Gluten and starch are proximate principles of plants; as oil, gelatin, and fibrin are, of animal matter.

The proximate principles of animal bodies have been arranged by Gay Lussac and Thenard under three heads. The first contains substances which are neither acid nor oleaginous; the second comprehends the animal acids; and the third includes the animal fats. Several of the principles belonging to the first division, such as fibrin, albumen, gelatin, caseous matter,

and urea, were shown by Gay Lussac and Thenard to have essential points of similarity in their composition. They all contain, for example, a large quantity of carbon, and their hydrogen is in such proportion as to convert all their oxygen into water, and their nitrogen into ammonia. No general laws have been established relative to the constitution of the compounds comprised in the other sections.

The ULTIMATE ELEMENTS of animal bodies admit of being arranged in two classes; one of which Dr. Prout classes as essential, the other as accidental. The first comprises carbon, hydrogen, oxygen, nitrogen. The following table exhibits the proportions, in which these elements are united to form the three commonest proximate principles of animals.

	Carbon.	Oxygen.	Hydrogen.	Nitrogen.
Fibrin	53.365	19.865	7.021	19.291
Albumen	52.883	23.872	7.540	15.705
Gelatin	47.881	27.207	9.914	16.988

The second class comprises almost every other simple body; but principally, sulphur, phosphorus, chlorine, fluorine, iron, potassium, sodium, calcium, magnesium.

The *decomposition* of animal or vegetable bodies is the return of their proximate principles to their ultimate elements. The process varies as the nature of the decomposed substance varies. In many instances changes supervene, which have the effect of retarding complete resolution. Different sorts of fermentation furnish products remarkable for the length of time they may be preserved unchanged. Where nitrogen is present, as in most animal and in some vegetable substances, the process of decomposition, characterized by its rapidity, its fetor, and the extrication of ammonia, is termed *putrefaction*. Within a short period after death, the human frame undergoes an evident change; the features become sharper; the cornea loses its brightness; the eyes sink. Then the neck and abdomen become discoloured; the body softens and exhales an offensive odour; the skin, from which the cuticle separates, turns successively green, and blue, and black; the corpse slowly dissolves, part combining with the atmosphere, part reduced to a liquid state, part mouldering to earth.

In order that putrefaction may take place, the body must be exposed to the conjoined influence of an elevated temperature,

of moisture, and of atmospheric air or air containing oxygen. If either of these agents is excluded, the progress of decomposition is arrested. Frozen provisions will keep for an indefinite period with little change except a diminution of their flavour. A dissected limb suspended in a current of air, loses its moisture by evaporation, becomes hard and of a brown colour, and subsequently remains for a length of time without undergoing further alteration. And a method has been successfully used of preserving the flesh of animals for many months free from taint, which consists in inclosing it directly after boiling in metal cases accurately soldered.

Certain substances are termed antiseptic, with which when animal matter is impregnated, the ordinary mode of decomposition is prevented, and another change substituted: after which, any further alteration is greatly retarded. Antiseptic substances are either of an aromatic nature, such as camphor, resins, volatile oils, and bitumens, which have been at various times employed in the process of embalming: or acids, sugar, certain neutral salts, as nitre and muriate of soda, which are principally used for culinary purposes, but some of which are serviceable in anatomy. A saturated solution in water of three parts of nitre to one of salt, or of nitre alone, injected into the blood-vessels, is found to retard decomposition sufficiently long to allow time for the ordinary process of dissection. Of the substances that remain, alcohol, which produces less change than any other antiseptic fluid in the appearance of parts immersed in it, is peculiarly fitted for the preservation of anatomical preparations.

The structure and composition of animal bodies are thus to be followed out in anatomy and chemistry. The province of physiology is to determine the forces with which the same bodies are temporarily endowed, and to explain their action. Upon these subjects the following pages will be employed. In this introductory chapter, their general character will be shadowed out.

What, therefore, it may now be inquired, are those changes, which, exhibited for a period by all organized bodies, constitute the phenomena of life.

The mucors and confervæ, the lowest of plants, may be adduced as the simplest examples of vitality.

The conferva rivularis, to select an individual instance, is a

green filament, finer than a hair, which is found in streams and in stagnant waters. It has no distinct root or leaves: it is sometimes attached by means of a disk to stones in the bank or at the bottom. Its structure is uniformly cellular, the shape of the cells being oblong.

The conferva rivularis, when living, is observed to increase in length, and to throw out filaments like branches. The added parts are similar in structure and composition to the first.

These phenomena, in which nearly all that is known of the vitality of the plant is comprised, imply several distinct operations.

The plant, in its increase in size and weight, borrows something from the medium in which it lives.

The material borrowed is converted into vegetable matter, or is assimilated to the chemical nature of the living body which contains it.

The newly assimilated matter is laid down as a part of the plant in a determinate shape and structure.

The assumption of food, its assimilation, and the deposition of the assimilated matter as a part of the frame, are the steps by which growth is accomplished, or in which nutrition consists. In the instance which has been given, the occurrence of these three operations is indeed established less by direct observation than by analogical reasoning; but in the higher plants, each part of the process admits of being shown: the imbibition of fluid by the radicles; its ascent in the vessels of the alburnum to the leaf, where its assimilation is accomplished; the subsequent descent of the assimilated fluid by the vessels of the bark to be used in the growth and nourishment of the plant,—are demonstrable by experiment. At the same time an additional phenomenon presents itself: the growing plant is continually eliminating water, and carbon or carbonic acid. Wherever vitality is active, a constant elimination of carbon takes place; and the exposure of the living plant or animal to atmospheric air or to air containing oxygen, is observed to be a necessary condition for effecting the separation of the superfluous element.

In the higher animals, other principles besides water and carbonic acid are continually in process of being thrown out of the system; these are contained in the urine, the perspiration, and other excretions. Further, there is satisfactory evidence, that in the early periods of life, if not during its whole term, the frame of animals is undergoing an internal change and

renovation. The nutriment which they take is believed to be used, not merely to add to their bulk, but to replace in each part of the frame the materials which have hitherto composed it; the old constituent elements being supposed to be simultaneously removed by a process of molecular or interstitial absorption, and to be afterwards in part or wholly expelled.

In the higher plants again, and in animals, an extrication of heat occasionally or continually takes place. It would be reasonable to view this function as an accidental result of the chemical changes which are in operation throughout the frame, were it not for the remarkable precision with which it is performed in the higher animals. In the perfect animal economy, what is termed a standard temperature is rigorously maintained; provision is made, not merely for getting rid of any accidental superfluity of heat, but likewise for furnishing an additional supply of caloric, when under opposite circumstances the animal heat may happen to be too rapidly abstracted. The importance of these provisions is shown by the consequences of exceeding their limits. If the temperature of the body be for any considerable time raised above, or lowered beneath the standard, the animal perishes.

Growth by nutrition is characteristic of life. In the higher animals it is usual to consider the process of internal renovation already adverted to as an essential part, if not as the main object, of nutrition; but to what extent, or with what interruptions this renovating process goes on, remains uncertain. Several parts in the living frame once formed from assimilated matter (the teeth for example), continue alive through their simple adhesion to organs in which renovation is presumed to take place: and there are instances even of entire organized bodies, that retain vitality for a length of time during the total suspension of every internal motion. The seeds of plants and eggs of animals, if adequately protected against air and moisture and extremes of temperature, continue alive for months and years. The vibrio tritici, a minute animalcule, which is the cause of the ear-cockles in wheat, when dried is to all appearance dead; but, after being kept for many days in this state, on being moistened, revives, and moves in a lively manner*. The same fact is well authenticated of many of the infusorial animals. A leech frozen and gradually thawed will

* Phil. Trans. vol. cxiii, p. 9.

sometimes live. After the preceding facts, it will appear less surprising, that a part of a warm-blooded animal, capable of being made the subject of such an experiment—the ear of a rabbit for instance—may be frozen so as to chip, yet when thawed will bleed and inflame and live.

Living beings are produced by a modification of that process which brings them to maturity. Generation in plants and animals consists in the formation of a germ, which in time separates from the surface upon which it grew, and becomes an independent living being. It was discovered by Trembley, that the naïs at one period of its existence spontaneously divides into two unequal parts: to the posterior segment, which is a third of the length of the animal, a head is formed, to the fore part a tail *. The growth of a germ or embryo upon a definite surface in a plant or animal, with its subsequent separation, presents no feature that essentially distinguishes it from the preceding marvellous instance.

Upon a strict analysis of the phenomena above enumerated, two properties admit of being indistinctly shadowed out, which concur with the laws common to living and to dead matter in their production.

I. The changes wrought upon the ingesta during assimilation may be ascribed to a principle of Vital Affinity. In order to give this term an equal value with the term gravity, physiologists require to ascertain the conditions, which essentially precede changes in the chemical nature of the elements which compose a living body. As the phenomena here adverted to strikingly correspond with known effects of chemical agency, it is highly probable, that both will eventually be found to depend upon modifications of the same general law.

II. The assumption of foreign matter, and its propulsion through the tubes of a living body, may be partially produced or promoted by capillary attraction, by elasticity, by impulse communicated from without, by gravity, by electrical attraction or repulsion. In the majority of instances, however, another principle is distinctly in operation. Various parts in animals and plants alternately contract and expand, or shorten and elongate themselves, or change from a straight to an incurvated figure, or from the state of relaxation to that of tension, under

* Mémoires pour l'Histoire d'un Genre de Polypes, p. 221.

circumstances which prevent our referring these phenomena to the agency of the causes above enumerated. The tendency inherent in certain living textures to pass alternately from one of these states to the opposite, is termed Irritability. We call the fibre of which the heart is composed irritable; and we suppose from the many instances in which the fact admits of proof, that the nutritive fluids in all living bodies have motion communicated to them by the contraction of the containing vessels.

All the phenomena of vegetable life may be explained upon the assumption of two vital properties, such as have been described, superadded to those of inert matter. Even the sensible motions of plants, and the discrimination which some evince in the direction of their growth, imply no further agency. On these occasions we sometimes, perhaps, feel half-persuaded that plants exhibit an obscure degree of consciousness; but on candidly examining the phenomena, however closely some of them may correspond with the effects of sensation and instinct, it appears certain that they flow from simpler principles. By such analogies, in which Nature especially delights, the vast interval that exists between minerals and plants is rendered less apparent; and the yet wider break between beings that have life alone, and those which both live and feel, is so artificially concealed, that we can scarcely determine at what point in creation it occurs.

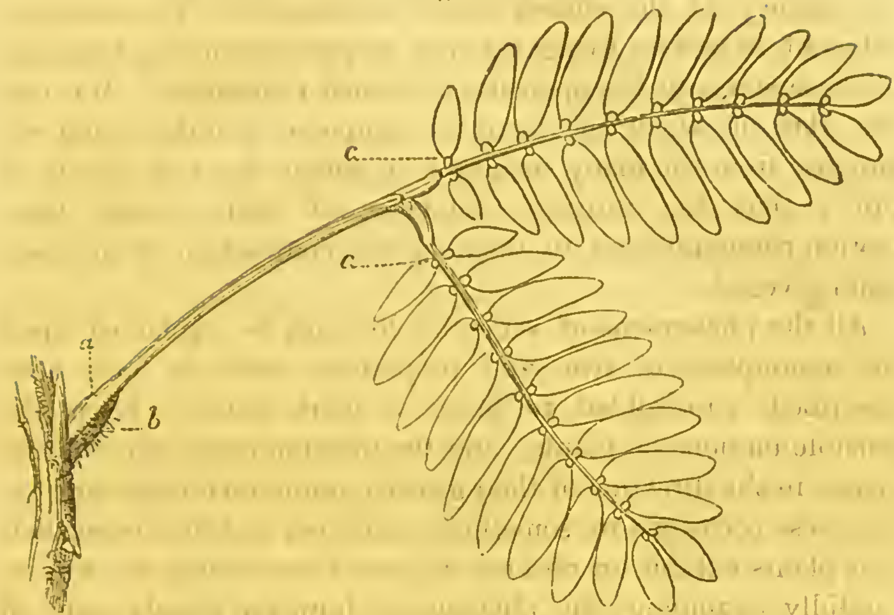
I made a series of experiments*, with the late Professor Burnett, in the summer of the year 1826, to determine the source and nature of the motion of the leaves of the mimosa pudica. Many of the facts which we observed, we afterwards found had been already described by Dr. Dutrochet, and were discovered many years earlier by Mr. Lindsay: an account of some of them will serve to illustrate the preceding remarks.

The sensible motions of the mimosa pudica are confined to the joints; 1, of the leaf-stalk or petiole with the stem or branch; 2, of the sub-petioles with the leaf-stalk; 3, of the sub-leaflets with the sub-petioles.

During the day-time the leaf-stalk is raised, the leaflets diverge, and the sub-leaflets are expanded, in the manner shown in the adjoined sketch.

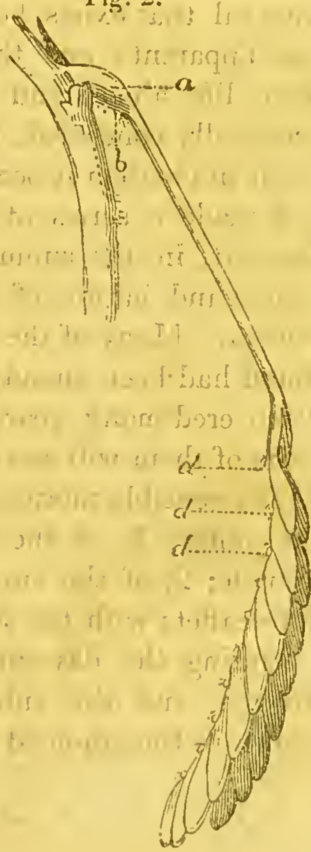
* See Brande's Journal for 1827.

Fig. 1.



In a plant sickly from exposure to cold, this position of the leaves is permanent; and no sensible motion has been observed to follow any kind of excitement that has been tried. When the plant is healthy, on the contrary, it is difficult to approach it without causing several of the leaves to fall. If the plant is shaken, all drop at once at their joints; at the same time the leaflets approach each other, and the sub-leaflets become folded in pairs, after the manner represented in Fig. 2.

Fig. 2.

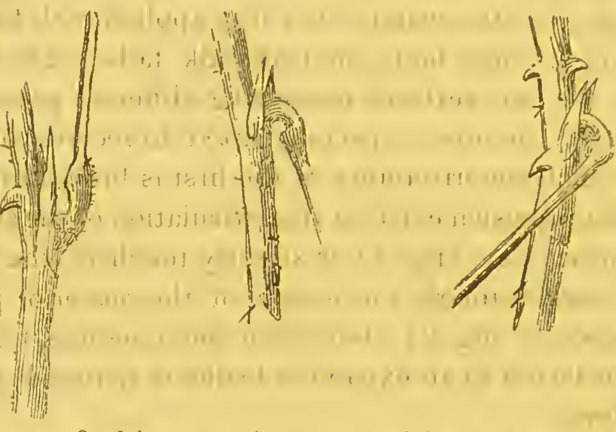


If the stimulus applied is partial; if, for instance, it consists in cutting a single sub-leaflet, that sub-leaflet instantly rises with its fellow; then the next pair, and so on in succession, till all upon the same leaflet are folded: the leaf-stalk then drops at its joint; and afterwards all the remaining leaflets close. If a sub-leaflet have been burnt, the excitement extends from one leaf to those adjoining; or if applied to the stem, or to the flower,

which in themselves have no motion, it will thence be propagated to the leaves.

A few points among these phenomena deserve to be more particularly remarked.

1. The motion, which takes place at the articulation, is produced by an excess of force, not on the side towards which the leaf is bent, but on the opposite. This is proved by cutting a notch in the intumescence of the joint; upon which the leaf-stalk becomes *permanently* bent towards the wounded side.



The effects of this experiment, which was first made by Mr. Lindsay, Dr. Dutrochet well explains, by comparing the action of the predominant side of the intumescence to that of a curved spring, which has been temporarily held in an extended position by an antagonist force, and is allowed to resume its incurvated figure. Or the intumescence may be said to consist of four such springs opposed to one another, of which the two that form the upper surface, distinctly possess irritability.

2. The substance, which conveys the excitement from one part to another, has been proved by original experiments of Dr. Dutrochet, not to be the bark or the pith, but the wood.

3. Professor Burnett observed, that when a single leaf with its leaf-stalk is removed with great gentleness from the plant, the irritability of the separated part remains for a time as lively as before. The detached leaf spreads its leaflets as soon as it has recovered from the shock attending its removal; upon the re-application of a stimulus it again closes them; after a time it again expands them.

4. It appears by facts which have been mentioned, that the leaf-stalk is depressed by the action of the upper portion of the

intumescence, *a* [fig. 1 and 2]: and that if *any* part of the plant is sufficiently irritated, this effect follows. But I discovered that there is *one* part better calculated than the rest to receive impressions; or on which impressions tell, that are too slight to produce action in the irritable substance of the plant, when applied elsewhere. This susceptible part is the under half of the intumescence *b* [fig. 1 and 2]: it is of a darker colour than the upper surface, and covered with strong short hairs. A steel point may be gently moved over, and even pressed against the upper surface without producing any sensible effect; but the instant that it is applied with the slightest contact to the under half, the leaf-stalk falls. Thus the intumescence has two surfaces possessing different properties: the one irritable, the other especially fitted to receive impressions, through which the irritability of the first is brought into action.

A similar provision exists at the articulation of the sub-leaflets. If the surface at *c* [fig. 1] is slightly touched, the sub-leaflet instantly rises through the action of the posterior part of the intumescence, *d* [fig. 2]: but when the experiment is reversed, and the surface *d* in an expanded leaflet is irritated, no sensible effect follows.

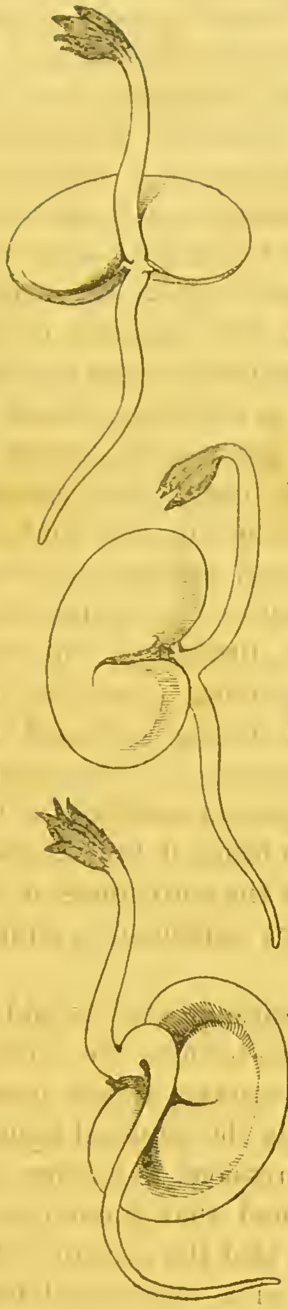
It is impossible not to be struck with the close analogy which holds between the phenomena last described and many of the instinctive motions of animals. In animals, as in the mimosa, one organ being stimulated, another and a different part acts: when a particle of dust, for example, is driven against the surface of the eye, the orbicular muscle closes the eyelids; when a brighter light falls upon the retina, the iris contracts. The two cases are nevertheless essentially different. In the first, sensation being excited upon one surface of a living animal frame, an instinctive action follows in another part. In the second, all that we know, or have reason to believe takes place, amounts to this, that one part of a plant being irritated, a physical impression is conveyed from it through the vegetable substance to another, which being thus excited assumes an incurvated figure.

The discrimination seemingly evinced by plants is a subject no less curious than the preceding. Climbing plants stretch towards objects calculated to support them: a shrub growing upon a wall, when it has exhausted the nourishment which its situation afforded, has been known to drop a long root to the

soil below. The daisy, in rank grass, bears a flower upon a long stalk : on a close shaven lawn, its flower is sessile. These and similar instances have again been occasionally ascribed to an instinct in plants : but nothing can be looser than the analogy upon which this conclusion is founded. In animals, instinct is a part of consciousness : and although it serves as a guide in the selection of proper nourishment, yet it exerts no direct influence upon growth. When, for example, an animal is transported from a colder to a warmer climate, the change which in some instances takes place in the character of the integuments, fitting the animal for its new abode, is not wrought by instinct. How illogical would it be to attribute instinct to plants, in order to account for classes of phenomena, which in beings, that unquestionably possess it, result from another principle. It is much more philosophical to suppose, that the growth of plants is determined by physical impressions alone, such as variations of moisture or temperature, and exposure to or deprivation of light; and that Nature, instead of imparting sense and perception to plants as their guiding principles, has attained her purpose by another method, having so framed and endowed the vegetable economy in accordance with the circumstances in which it is placed, that the common accidents of the elements and of the seasons are likely to bring it to perfection. Several remarkable examples go to prove the correctness of the preceding views, out of which it may be sufficient to adduce the following.

It is well known, that in whatever position a seed is laid in the ground, the plumule invariably rises towards the surface of the soil, while the radicle, on the contrary, shoots downwards, something in the manner shown in the adjoined figures. Upon the hypothesis that physical impressions determine the growth of plants, we should expect to find that gravitation is in this instance the influential cause; or that the growth of the radicle necessarily follows the direction of a mechanical force or tendency to motion, while that of the plumule goes against it.

Mr. Knight ascertained this solution to be just, by experiments, in which another force was made to supersede, or to co-operate with, that of gravity. Seeds of the garden bean, which had been previously soaked in water, were attached at short distances along the circumference of a vertical wheel, which was made to perform more than 150 revolutions in a



minute. In a few days the seeds began to germinate. In their growth the plumule of each tended towards the axis of the wheel, the radicle in the contrary direction. In this case, owing to the vertical rotation of the wheel, the influence of gravity was neutralized; in its place a centrifugal force was substituted, by which the growing seed was influenced exactly as before by gravity. In another experiment, beans similarly prepared were attached to the circumference of a horizontal wheel, which was then set in rapid motion: the result was not less conclusive than in the former instance: the plumule of each seed was observed to grow in a direction upwards and inwards, while the radicle tended downwards and outwards, that is to say, in the diagonal of the two forces, by both of which, according to the hypothesis, it should have been blindly influenced *.

From these and similar instances it appears reasonable to conclude, that the vital endowments of plants are limited to two; irritability namely, and some modification of chemical affinity. What an immeasurable interval between *their* mode of existence and that of animals.

The hydra viridis, a polyp, which in complexity of organization is infinitely below the higher plants, in its animal functions is placed as far above them. It is observed to move

* Phil. Trans. vol. cvi, p. 108.

spontaneously from place to place, to attach itself in preference to the sunny side of the vessel of water in which it is exposed to the study of the curious, to seize its prey by means of filamentous tentacula and to force it into its digestive cavity; in short, to exhibit a succession of actions, which compel us, if we would not deny consciousness to the dog and to the elephant, to attribute sensation and volition to this little gelatinous bell.

In the polyp, life and consciousness are equally distributed through one uniform texture. An unbroken chain of improving organization may be traced from this zoophyte upwards to man: digestive organs, a vascular system, a respiratory apparatus, successively appear in the more elaborate frame. While these parts are produced, which are appropriated to nutrition or to the functions of vegetative life, the nervous system is developed, which becomes the exclusive seat of consciousness.

When a polyp is divided (and the same experiment is followed by the same result much higher in the scale), it becomes two living animals. But as the type of organization further improves, the animal becomes individualized; when divided, the separate portions are found to be incapable both of independent existence; either both perish, or one alone survives: the animal now consists of a single series of organs, the functions of which exert a reciprocal influence, and combine to sustain life.

It is usual to arrange the functions distinguished in the human economy under the two classes above adverted to, one as the vegetative or organic class, the other as the animal or sensitive.

By the former, nutritious matter is separated from the food, is conveyed through the lacteals into the veins, becomes blood, and is circulated through the body, which grows and lives through its influence: or component particles of the body are absorbed, thrown into the circulation, and what are useless eliminated: or the embryo is formed and fœcundated, and having attained to fœtal maturity, is born.

By the latter, the human being, through sensation, becomes acquainted with the world around him, is led to the instinctive gratification of his appetites, or under the guidance of reason directs a succession of voluntary efforts towards higher purposes.

The preceding division is not, however, strictly applicable

to the plan of a systematic work upon Physiology. Almost every function is partly sensitive, partly vegetative. Thus we discriminate the quality of food by sensation, and swallow it voluntarily to allay an appetite; but of its digestion we are unconscious, and cannot by an effort of the will accelerate or retard it.

In this dilemma, it is obvious that the adoption of a very rigorous method is impracticable, or would serve to give about as clear a notion of life, as a separate description of the single threads in a piece of tapestry would of its design. Among the circle of functions, again, it is difficult to determine with which to begin; but where selection is not easy, it may be presumed that the advantages of different plans are so equally balanced, as to leave it a matter of small importance, which is chosen.

CHAPTER II.

OF THE BLOOD.

If any subject is fitter than another to occupy the first place in a physiological treatise, it is the history of the blood. From this fluid the body is formed; by its influence life is immediately sustained. It consists, on the one hand, of new materials freshly elaborated from the food, and on the other, of the old constituent elements of the frame, that have been returned to it through the function of molecular absorption. The frame that was, the body that is to be, may be said therefore, without too bold a figure, to exist in solution in the blood.

An assimilated fluid moving in set currents through the frame, is an early feature in the vital œconomy; and modern researches have brought this phenomenon to light in instances that are wonderfully low in the scale of organization. In the year 1820 Schultz observed the motion of a fluid containing minute globules in the vessels of the chelidonium; and every one is now familiar with the appearance of a double current in the joints of the chara. The visible motion of fluids in plants is, however, partial; Schultz gave it the name of cyclosis, to distinguish it from a real circulation.

Appearances resembling vegetable cyclosis have been recently discovered in a great number of polypiferous zoophytes, by Mr. Lister. In a specimen of the tubularia indivisa, when magnified one hundred times, a current of particles was seen within the tubular stem of the polyp, strikingly resembling in the steadiness and continuity of the stream, the vegetable circulation of the chara. The general course was parallel to the slightly spiral lines of irregular spots on the surface of the tube, ascending on the one side, and descending on the other. In various species of sertulariæ the stream does not flow in the same constant direction; but after a time, its velocity is retarded, and it then either stops, or exhibits irregular eddies previous to its return in an opposite course; and so on alternately, like the ebb and flow of the tide. If the currents be

designedly obstructed in any part of the stem, those in the branches go on without interruption, and independently of the rest.

Thus early is shadowed out a function, which in the higher animals is of such moment to life, and the maintenance of which is so carefully provided for. To form an idea of the human circulation (or of that type common to mammalia and to birds, and with slight modifications extending so much lower), the student may begin by imagining the entire frame to be drilled through with an all-pervading network of membranous capillary tubes. These vessels in the human body are $\frac{1}{3000}$ of an inch in diameter. They are more numerous in some parts than in others; where the network is closest, and the capillaries are therefore the most numerous, if the vessels are injected with size and vermilion, the part assumes as deep and uniform a tint, as if it had been dyed scarlet.

Into this network of capillaries pervading every part, florid or scarlet coloured blood is perpetually flowing, being conveyed thither by minute arteries, which are the ultimate branches of a single primary arterial trunk, called the aorta, that issues from the left ventricle of the heart. Or the capillaries of the system admit of being represented as the final subdivisions of the branches of the aorta. When passing through the systemic capillaries the blood changes in colour from scarlet to purple.

The vessels into which the purple blood escapes from the capillaries are termed veins; or the veins may be described as formed by the union of two or more capillaries; coalescing, they successively form larger and larger trunks; these end at last in three great vessels, which open into the right cavity of the heart, and pour the dark blood into it.

Scarlet blood is commonly called arterial, because blood of this colour is usually found in the arteries of the body. Dark coloured blood is commonly called venous, because the veins of the body usually contain dark blood. These terms, however, are only just, when applied to the blood in the systemic vessels. In the pulmonary circulation the facts are reversed. The purple blood is thrown out of the right cavity of the heart by a single vessel, which is in structure an artery, and the branches of which are distributed in the lungs in the same manner as those of the aorta are distributed through the entire frame. After many subdivisions the branches of the pulmonary artery

terminate in a network of capillaries, which is spread out over the entire membrane lining the air-cells: in these the blood again changes its colour; recovering its former hue from purple it now becomes florid.

This phenomenon appears at first sight a very simple one. When purple blood that has been drawn from a vein is exposed to atmospheric air, the surface exposed acquires a florid scarlet colour: at the same time it is found, that the oxygen of the air so employed has been converted into carbonic acid. In this experiment it is evident that the oxygen of the air combines with the carbon of the blood, and abstracting it, leaves the blood of a brighter colour. Breathing may be considered as a process through which a parallel effect is produced upon the purple blood in the living body. In the capillaries of the lungs, the venous blood is continually exposed to the influence of fresh atmospheric air, drawn in at each inspiration. In consequence of this, the venous blood loses its dark hue: at the same time oxygen disappears from the air which is breathed, and carbonic acid is left in its place.

The blood, purified of its superfluous carbon or carbonic acid in the lungs, is finally transmitted by the pulmonary veins to the left cavity of the heart, from whence it is again to be impelled into the aorta: in other words, it is brought back to the point at which we began to trace its course. Thus is the blood alternately thrown through the whole frame which it vivifies and nourishes, but in which its composition and its properties become impaired, and through a single organ in which it is renovated by exposure to the atmosphere, and rendered fit for the support of life.

The name of Harvey has been immortalized by the discovery of the circulation. The simple and conclusive argument which our great Physiologist adduced in support of his theory may be thus stated.

An animal may be drained of blood by opening either the large arteries or the large veins. The blood therefore must have a natural passage from one of these sets of vessels into the other.

If an artery is tied, and then punctured on both sides of the ligature, the blood rushes violently and by jets from the puncture nearest the heart, but flows without force from the remoter puncture. It follows, that there is a natural current of the blood along the arteries in the direction *from* the heart.

If a vein is obstructed by pressure, it swells or fills with blood on the side remote from the heart, while the part between the point of obstruction and the heart does not swell. It follows, that there is a natural current of the blood in the veins setting *towards* the heart.

Finally, the valves in the veins are so placed that "they give a free passage to the blood towards the heart, but oppose the passage of the venal blood the contrary way."

To this body of proof may now be added the fact, that in transparent parts of living animals, the blood may *actually be seen* to be constantly flowing, as Harvey taught, from the arteries, whether systemic or capillary, through the capillaries into the veins.

Blood when flowing from a vessel of the living body is an unctuous liquid, of a faint odour and saline taste, of the temperature of 98° of Fahrenheit's thermometer: its specific gravity varies from 1038 to 1059 *.

Dr. Davy ascertained that the temperature of arterial blood in a living animal is about a degree higher than that of venous blood. The temperature of blood when flowing from the carotid artery of a lamb was found to be 105°, from the jugular vein 104°. In lambs killed by the division of the great vessels in the neck, the temperature of the left side of the heart was 106°, that of the right side 105.5°. In oxen that had been knocked down, the blood being of the same colour in the arteries and veins, the temperature of the arterial blood was found to be 101° or 101.5°: that of the venous blood, 100°. In a sheep, in which the specific gravities of arterial and venous blood were 1049 and 1051, the relative capacities of the two fluids for caloric were 913 and 903 †.

When venous blood is detained in a vein, its colour becomes darker.

When arterial blood is kept at rest in a living vessel, it gradually acquires the properties of venous blood; as may be seen on slackening a tourniquet after an amputation, when the first blood that issues from the divided arteries is of a dark colour. If arterial blood is placed *in vacuo*, or is exposed to nitrogen, hydrogen, or carbonic acid, it loses its florid hue ‡.

* Dr. Davy's Observations, &c., Edinburgh Medical Journal, vol. xcv, p. 245; and Dr. Scudamore on the Blood, p. 36.

† Phil. Trans. vol. civ, p. 593, et seq.

‡ Thomson's System of Chemistry, vol. iv, p. 615.

Extravasated arterial blood remains florid for several minutes; after an interval it is found to have coagulated, and to have acquired a dark colour*.

Blood flowing from a vein has been observed, when fainting has supervened, and under some other circumstances, to lose its usual appearance, and to become florid †.

A halitus is seen to rise from the surface of blood recently drawn, upon the same principle that a sensible evaporation takes place from other liquids at an elevated temperature.

Blood, that after having been drawn has stood a few minutes, is observed to be covered with a thin pellicle, and afterwards the whole quantity gradually becomes a gelatinous solid. This change is termed the coagulation of the blood. On an average it commences about three or four minutes after blood is drawn, and is completed in seven or eight. Dr. Gordon found the coagulating portion of a quantity of blood warmer than the rest by 6° of Fahrenheit's thermometer. On repeating the experiment upon blood drawn from a person labouring under inflammatory fever, the rise of the thermometer is said to have been no less than 12° ‡. But there is reason to suspect that some error may have crept into these observations. Mr. Hunter detected no extrication of heat during the coagulation of the blood of a turtle, the temperature of which was the same as that of the air. Dr. Davy mentions, that he has repeated Mr. Hunter's experiment with the same negative results, upon the blood both of the turtle and of the shark. Dr. Davy remarks as a parallel phenomenon to the present, that when serum is coagulated by means of dilute nitric acid, no appreciable alteration of temperature occurs.

Mr. Brande observed, that during the coagulation of the blood carbonic acid is disengaged: this appeared to happen to an unusual extent in blood drawn soon after a meal §. Dr. Davy, however, adduces several observations in opposition to those of Mr. Brande; and denies the existence of free carbonic acid in the blood.

In a short time after coagulation, drops of a yellowish liquid are seen to exsude from the clot, which goes on thus spontaneously to separate into two elements; the solid part is termed

* Hunter on the Blood, p. 68.

† Hewson's Experimental Inquiries, p. 25; Mayo's Pathology, p. 480.

‡ Thomson's Annals, vol. iv, p 139.

§ Phil. Trans. vol. cx, p. 6.

the crassamentum, the fluid part the serum of the blood. The crassamentum is usually estimated to be a little less in quantity than the serum. The proportion of serum is greater in persons of a debilitated habit of body than in those who are strong: it is greater again when coagulation takes place under a low degree of temperature. The slow contraction of the coagulum has not entirely ceased till the fourth day.

Serum, when exposed to a temperature of 160°, and still more readily at 212°, is converted into a white coherent mass, from which a fluid termed the serosity may be obtained by pressure. The coagulated part is albumen. The same principle exists in the serosity, but is suspended by the presence of an alkali. Atmospheric air in contact with serum does not lose oxygen and acquire carbonic acid, as when in contact with blood. The component parts of serum, according to Dr. Marcet, are,

Water	900.00
Albumen	86 80
Muriates of potash and soda	6.60
Muco-extractive matter	4.00
Subcarbonate of soda	1.65
Sulphate of potash	0.35
Earthy phosphates	0.60
	1000.00

The specific gravity of serum is 1028. Albumen, which forms so large a part of the serum of the blood, is the principal element in the composition of the skin, and of the cellular and vascular tissues.

When the crassamentum has been repeatedly washed, it becomes a glutinous and fibrous mass of a greyish colour: the water employed is rendered red. The greyish substance is termed fibrin, and appears to be of the same nature with the material left after muscle has been boiled for a considerable length of time. It forms the tough substance which is met with after death in the cavities of the heart and great vessels, and in aneurysmal sacs in which it is commonly disposed in layers. Dr. Davy found the specific gravity of the fibrin of the blood, examined in three different instances, to be 1046, 1057, and 1060. The quantity of dry fibrin that may be obtained from blood varies from .13 to .47 per cent.

The colouring matter of the blood resides in innumerable

particles, which are readily discovered with the assistance of a microscope, upon examining serum, in which a portion of the coloured clot has been broken down. The form of these particles in human blood, which was determined by Dr. Young, is that of a silkworm's egg: they are circular discs, extremely thin, with rounded edges, and with a central depression on either flat surface: their diameter is $\frac{1}{5000}$ of an inch, according to the observations of Dr. Hodgkin and Mr. Lister, with which my own exactly coincide. Their specific gravity Dr. Davy estimates at about 1087. When immersed in water they lose their colouring matter, and with it much of their specific gravity. In this state they are supposed to consist of albumen.

Mr. Brande discovered, that the colouring matter is an animal substance of a peculiar nature, susceptible, like the colouring matter from vegetables, of uniting with bases, and applicable to the art of dyeing. The most effectual mordaunts for the colouring matter of the blood are salts of mercury, especially the nitrate and corrosive sublimate.

Mr. Brande ascertained that iron does not exist in greater proportion in one element of the blood than in another *.

Dr. Stevens has shown that the addition of certain neutral salts to the blood drawn out of the body heightens its florid colour; and that when the blood has been deprived of its salts, it no longer becomes florid on exposure to oxygen.

The coagulation of the blood and its separation into serum and crassamentum are phenomena, which may be regarded as the result of its chemical composition no less than its previous continuance in a fluid state. The circumstances under which the blood exists vary, and the reciprocal attraction of its elements is changed. Our knowledge upon this subject is, however, very imperfect, and amounts but to a bare enumeration of instances, in which the coagulation of the blood takes place readily, or slowly, or is entirely prevented.

The tendency of the blood to coagulate, when drawn from the living body, is not affected by moderate differences in temperature †. Blood at 57° and 105° coagulates in the same time as at 98° ‡: as readily when exposed to azote, nitrous gas, nitrous oxide, carbonic acid, and hydrocarbon, as when exposed to atmospheric air §.

* Phil. Trans. vol. cii, p. 90.

† Hewson, l. c. ‡ Hunter, l. c.

§ Researches on Nitrous Oxide, by Sir H. Davy, p. 380.

Blood coagulates quickly when placed in a receiver, from which the air is immediately exhausted; when drawn from a small orifice into a shallow vessel; when exposed to atmospheric air at a temperature of 120°; more rapidly when the body is exhausted by hemorrhage, than when it exists in strength and vigour.

The coagulation of the blood admits of being delayed: 1. By freezing. A portion of the jugular vein of a rabbit tied between two ligatures was removed with the blood contained in it, and frozen: when thawed, the blood became liquefied, and coagulated. 2. By low temperatures above the freezing point. Mr. Hewson placed blood in oil at a temperature of 38°: at the expiration of six hours it continued fluid; but being then allowed to attain a warmer temperature, it became coagulated in twenty-five minutes. 3. By mixture with certain neutral salts. If half an ounce of Glauber's salt be mixed with six ounces of fresh blood, the mixture does not coagulate: but on the addition of a double quantity of water coagulation takes place.

Other circumstances retard coagulation. Blood coagulates slowly when drawn from a large orifice into a deep vessel; when taken from a person in vigorous health, or from one labouring under inflammation; when detained at rest in a vein of a living animal between two ligatures. On a repetition of the last observation, Mr. Hewson found the blood two-thirds fluid after three hours and a quarter had elapsed: the blood being then exposed to the air, entirely coagulated. When the experiment was varied by blowing air into the vein, the blood was found to have coagulated in a quarter of an hour. Mr. Hunter mentions, that two leeches which had been applied were subsequently preserved ten weeks. At the expiration of that time they contained a considerable quantity of blood, which appeared like blood recently drawn from a vein, and coagulated when exposed. The following incident is to the same purpose. On tapping a hydrocele, a small vessel was wounded, and the blood escaped into the sac: when the tapping was repeated sixty-five days after, the blood came out thickened, but then coagulated and separated into different parts *. Blood, extravasated through the rupture of vessels, often remains for a considerable time in a fluid state.

* Hunter on the Blood.

In some instances a modified coagulation takes place. Mr. Hewson found, that if blood was kept at a temperature of 38° for twenty-four hours, it had become thick and viscid, but did not coagulate on regaining a higher temperature. In torpid bats, Mr. Cornish found the blood thickened, but it soon recovered its fluidity on motion and heat.

The blood does not coagulate when the causes that are capable of delaying the process have continued to operate beyond a certain period. If blood freshly drawn be kept for some time in very brisk motion by being stirred, it often will not coagulate at all. In persons killed by lightning, by suffocation, by blows on the stomach, or through the influence of acrid vegetable poisons, or in persons dying from violent mental emotion, or perhaps in all instances of sudden death unattended with hemorrhage, and occurring to persons just before in full possession of health and strength, the blood is found in a fluid state. A temporary change in the nature of the blood of a like kind is found in certain diseases. Mr. Hewson mentions, that a woman was bled in a fever which came on soon after delivery: her blood did not coagulate on being exposed to the air, but appeared like a mixture of the red globules and serum only, the globules having subsided to the bottom in the form of a powder. She died three days afterwards; and upon examination the blood was observed to have coagulated in the vessels, and a tough white clot was found in each auricle of the heart: the blood that had been taken during her life did not coagulate till at the heat of 160°. The blood excreted in healthy menstruation does not coagulate.

In reviewing these phenomena, it cannot but appear deserving of notice, that the circumstances, which are found in physiological experiments the most efficient in retarding the coagulation of the blood, are conditions essentially present during life. These are, motion, and the contact of living surfaces. The blood at a temperature near its standard temperature, and unexposed to any very active agent, is sure to coagulate, unless *both* of these conditions are present. Thus in a living vessel in which the blood is detained at rest by ligatures, it clots, although slowly; and when blood has been drawn in the usual manner from a vein, if it be kept in gentle motion only, it yet coagulates.

I suppose it is upon the retarding or preventive influence of the contact of living surfaces, that we are to explain the facts,

that blood drawn into a deep vessel and in a large quantity coagulates slowly; and that the blood of those who are destroyed in full health by sudden and violent death, unattended with hemorrhage, as by suffocation or through the action of prussic acid, does not coagulate at all. In the latter class of instances, although consciousness is suddenly extinguished, yet the unexhausted animal tissues probably retain for several hours a residuum of vitality. In such cases again it is remarkable that, as in life, the blood speedily coagulates, if through rupture of a vessel it becomes extravasated; what remains in the vessels is through their vitality prevented coagulating for so long a time, that the tendency has ceased, before it can have been efficiently exerted.

The final causes of the coagulation of the blood, or the objects attained by it in the vital economy, are very striking. In a common incised wound in which no large vessels are divided, the last blood which flows, clotting between the cut surfaces, glues them together; and then by a wonderful process, the thin intervening layer contributes to produce a renewal of vascular continuity between the newly adherent parts. To serve this purpose entirely, however, the intervening layer of blood must be the thinnest film: a sensible quantity of clot intervening may indeed for a time unite the wound, but after a few days, instead of becoming organized it loses its hold and is thrown off. Nevertheless, a considerable clot of blood adhering to a vascular surface is occasionally found to have received blood into a series of irregular tubes, which appear to form spontaneously within the coagulum. These tubes Sir Everard Home supposed to be wrought by the extrication of bubbles of carbonic acid during the process of clotting.

Another use of the coagulation of the blood, is to stop hemorrhages resulting from the giving way of large vessels. An essential element in this process is the clotting of the blood in the extremity of and around the ruptured vessel: and it cannot but excite admiration, that this important process is hurried on by Nature, or the tendency towards it heightened, in proportion as the frame is nearer to complete exhaustion.

CHAPTER III.

OF MUSCULAR ACTION.

Various textures in animals are observed to exist at successive periods in two different states, to be at one time elongated, at another shortened. The change from the one state to the other is the beginning of motion. The phenomena attending the greater number of cases in which motion is thus produced, have common points enough to authorize us in ascribing them to one property, which has been termed Irritability. They are certainly not effects of elasticity or of gravitation, nor are they expansions and contractions of bodies caused by changes of temperature; and although they correspond in some respects with the results of galvanic action, yet the analogy is as yet too loose and incomplete to warrant any confident expectation that the movements of irritable parts will be proved to depend upon a modification of the electric principle.

The parts of the human frame which possess irritability are, muscular substance, the substance of the uterus, the fibrous coat of arteries, the unattached margin of the iris, some parts or the whole of the skin, and perhaps the dense texture which is employed in forming excretory tubes. In the phenomena of muscular action alone, which form the subject of the present chapter, a surprising diversity exists.

Muscular substance is what is commonly called flesh in animals; varying in different genera and species, in different individuals of the same species, in different parts of the same body, both in firmness and colour, it presents in every instance the common point of a fibrous structure. Nevertheless, in the same animal the deeper colour and firmer texture of a single muscle or class of muscles may be taken as a proof, that it has been more frequently and powerfully exerted than others, and through use has acquired greater strength.

The flesh of the human frame is of a reddish brown colour

in the muscles of the trunk, head, and limbs, and in the heart; of a pale grey in the muscular coat of the alimentary canal and of the bladder. But upon maceration in water it is found in each case to be reduced to little more than a colourless fibrin. The water that has been employed contains albumen, gelatin, extractive matter, and various salts. Perhaps the most remarkable circumstance, which has come to light in this investigation, is that nitrogen exists in larger proportion in the muscles of animals with red blood, which possess the greatest variety of functions and enjoy them in the most perfect state, than in those of fish or reptiles. The same difference is observed in the muscles of animals of the same species, between the adult and the young *. In young animals, it appears that the muscles as well as the membranes and bones contain a considerable quantity of gelatin; but as they advance in age the gelatin disappears, and is replaced by albumen. Fat, or oil contained in delicate membranous cells, is found in the substance of muscles, more coarsely wrought into the texture of some than of others, and in age than in youth.

The muscular tissue consists of flattened bands or lacerti of soft flesh, connected together by a thin transparent elastic membrane. Each of these bands admits of separation into slender strips or fibres, which again may be resolved into others yet finer. All the fibres are individually invested and joined together by processes of the same membrane which clothes the lacerti.

Within the last few years it has been very generally believed, on the authority of Meckel, Home, Bauer, and Dr. H. M. Edwards, that the muscular fibre is ultimately composed of globules combined in a linear arrangement. More recent investigations, made by Dr. Hodgkin and Mr. Lister with the aid of the achromatic compound microscope in the possession of Mr. Lister, have shown this appearance to be an optical illusion. The following extract from the observations of these gentlemen contains the result of their inquiries.

"The muscular tissue may be easily seen with the naked eye, or with the assistance of a comparatively feeble lens, to be composed of bundles of fibres, held together by a loose and fine cellular membrane; and these fibres are again seen to

* Bostock's Elementary System of Physiology, vol. i, p. 152.

consist of more minute fibrillæ. It is difficult to push the mechanical division much further; for the softness of the muscular substance is such, that it is either crushed, or breaks off rather than admit of further splitting. If a piece of one of the most delicate of the fibrillæ last arrived at, be placed on a piece of glass in the field of the microscope, lines may be seen parallel to the direction of the fibre, which show a still further division into fibres.

"Although no trace of globular structure can be detected, *innumerable very minute, but clear and fine parallel lines or striæ, may be distinctly perceived transversely marking the fibrillæ.* In some instances these seem to be continued nearly or quite at right angles, completely across the fibril; but frequently the striæ in one part are opposite to the spaces in another, by which arrangement a sort of reticulated appearance is produced. The striæ are not in all specimens equally distant; but this may, perhaps, be owing to the elongation or contraction of the fibre. We have discovered this peculiar and very beautiful appearance in the muscles of all animals which we have yet examined; and, as we have seen it in no other tissue, we have been induced to view it as a distinguishing feature of muscle *."

Muscular parts receive a large supply of blood. The veins in muscles have numerous valves. Lymphatics have not been traced to any distance in the substance of muscles.

Nerves are distributed to all muscles, but in a larger proportion to some than to others, to the voluntary than to the involuntary: their disposition is thus described by MM. Prévost and Dumas. The trunk of a nerve and its first branches penetrate between the muscular fasciculi in a tortuous course, the exact direction of which appears indifferent. But the minute filaments, in which each branch ends, are found invariably to traverse the muscular fibres at a right angle and at short distances from each other, and then either to return to the same nerve, or to join a neighbouring branch: thus a nerve terminates in muscles by innumerable delicate loops; or the nervous filaments distributed transversely through muscular substance, communicate equally at either end with the brain or spinal cord. This disposition of parts is not observed

* Philosophical Magazine and Annals, Aug. 1827.

without difficulty in the opaque flesh of warm-blooded animals, but is readily seen in the thin transparent muscles of frogs. Several partial instances of a like nature have been long known to anatomists. The branches of the portio dura are found to unite by slender twigs with those of the three divisions of the fifth nerve upon the face; and in the tongue the union is equally distinct of twigs of the ninth nerve with twigs of the gustatory. It is remarkable that in many of these familiar instances the junction that takes place is between sentient nerves and nerves of motion.

It has been already observed, that muscular parts are found during life in one or other of two conditions, which naturally alternate, in relaxation or tension, in repose or in action.

A muscle when relaxed is soft and pliant, yields readily to lateral pressure, and is easily extended in the direction of its fibres. At the instant of becoming relaxed, muscular fibres always exhibit some degree of elongation, which, however, in many instances is extremely slight. It is uncertain from what cause this effect proceeds : under ordinary circumstances, some external force contributes to produce it, at least when it occurs in voluntary muscles : but in the heart, the forcible elongation of fibre, that takes place upon its relaxation, clearly results from some inherent property, which, in the want of proof, we may suppose to be either elasticity, or a part of irritability. On the other hand, muscular fibres, during the state of relaxation, are capable of becoming shorter. If we bend the elbow of an infant when lying asleep, the bicipital flexor becomes shorter in proportion as its attachments are approximated, but continues still disposed in a straight line between the shoulder and the elbow. The latter instance, however, should perhaps rather be considered as an effect of that low degree of action called the tone of a muscle, than as a phenomenon of relaxation.

A muscle, when in action, is hard, rigid, resists extension, and has a forcible tendency to shorten in the direction of its fibre. The rigidity depends less on the degree of shortening produced than on the force exerted. If a heavy body be held out nearly at arm's length, the palm of the hand being directed upwards, and the elbow slightly bent, the bicipital flexor will be found considerably more rigid, than when using less effort we completely bend the elbow joint and supinate the wrist. A

muscle in action, if counteracted by an equal force, has its tendency to shorten neutralized, and remains tense without any diminution of its length: and if opposed by a force superior to its own, admits even of being elongated during its most powerful action.

The relaxation of muscles seldom contributes directly to the performance of a function, or only contributes to this end by permitting the influence of other forces to be fully exerted. The action of muscles, on the contrary, has the most extensive, important, and direct application in the animal œconomy. By muscular action, for example, the joints are knit, and the frame of the skeleton is sustained in fixed positions or is carried forward in locomotion, or the cavities of the trunk are alternately enlarged or contracted, or the contents of the hollow viscera are expelled.

Action may be produced in all muscles during life or soon after death by various stimuli; by mechanical irritation, as for instance by the simple contact of a foreign body, and still more forcibly by cutting, tearing, or pinching the exposed fibre; by chemical excitement, as upon the application of diluted acid or alkaline fluids, and of different neutral salts; or by electricity.

A muscle in action, if allowed to become shorter, gains exactly in thickness what it loses in length. This I ascertained to be the case by the following experiment. The ventricular portion of the heart removed from a large dog immediately after death by hanging, was immersed in warm water contained in a glass vessel, which was closed below with a ground glass stopper, and terminated above in an open vertical tube one-third of an inch in diameter. The ventricles continued alternately to contract and dilate for a considerable length of time, during which the water stood at the same level in the tube, not sensibly rising and falling by the varying condition of the muscular fibre*.

The change in form, which muscular fibres assume during their action, is thus described by Dr. Hales.

"If," says he, "the skin be removed from the belly of a live frog, and the abdomen opened on each side, so as that its straight muscles may by drawing a little on one side have a

* Anatomical and Physiological Commentaries, vol. i, p. 12.

strong focal light cast on the inside of them; if in this posture these muscles be viewed through a good microscope, the parallel fibres of the muscles are plain to be seen, with the blood running alternately up and down between each fibre in capillary arteries so fine, that only a single globule can pass them. If the muscle happens to act while thus viewed, then the scene is instantly changed from parallel fibres to series of rhomboïdal pinnulæ, which immediately disappear as soon as the muscle ceases to act. It is not easy to get a sight of this most agreeable scene, because that on the action of the muscle the object is apt to get out of the focus of the microscope; but those who are expert in the use of these glasses may readily move them accordingly. I have found small frogs best for this purpose, namely, such as are not above a third or a fourth of their full growth. Stimulating the foot of a frog will sometimes make it contract these muscles. The frog must be fixed in a proper frame. If repeated observations were made on the muscles thus in action, it might perhaps give some farther insight into the nature of muscular motion *."

The recent researches of MM. Prévost and Dumas explain the change in form of each single fibre, from which the preceding appearance results. The ventral muscle of a frog so placed in a frame that a current of the galvanic fluid might at pleasure be directed through it, was examined in a microscope. When excited to contract, the fibres were seen to become bent at numerous angles into zigzag lines. When the stimulus was discontinued, the part regained its former length, and the fibres their straight direction. The angles were observed to be placed at nearly equal distances, and corresponded exactly with the point of intersection of nervous filaments. These circumstances are stated to have been made out in the muscles of warm-blooded animals, and no less in the muscles of the trunk and limbs than in those of the hollow viscera †.

When the ovary of the frog is full of spawn, the abdominal muscles are extended considerably beyond their habitual length. Upon being detached from the body, when in this condition, they are found to lose at once a third of their accidental elongation: but during this shortening, the fibres, according to Messrs. Prévost and Dumas, preserve their straight direction;

* Hæmastatics, p. 59.

† Magendie, Journal de Physiologie, vol. iii, p. 301, et seq.

and only when subsequently excited by galvanism to further action, are thrown into zigzag lines.

The retraction of the detached muscle in the preceding instance, is one of several phenomena which are said to depend upon muscular tone. Through this cause, if quickly after death a muscle in its medium state of extension be divided transversely, the separate portions instantly recede to some distance from each other. The same result of course ensues upon the division of a muscle in the living body; and as Bichat ascertained, the retraction is equally prompt and energetic, whether the nerves of the part have been previously cut through or not. It is remarkable that the separate portions which have retracted, if excited, shorten further, and then again become elongated to their last dimension. There are other instances, to which the term muscular tone has been applied, which depend upon a different cause. If the nerves of the face are divided, the features no longer remain supported in their usual expression; their muscular tone is gone, and they drop from their weight. On the other hand, the contraction by which a muscle accommodates itself to the flexion of a joint, or to the shortening of a bone that has been broken and ill set, is certainly independent of its nerve.

Repeated or continued exertion of muscular parts exhausts their irritability. When fatigued, we are conscious that our muscular frame has become temporarily weaker. A muscle repeatedly stimulated in a physiological experiment at length ceases to act. Dr. Wilson Philip ascertained, that this mode of exhaustion ensues even sooner when the part is left in communication with the brain, than when its nerves have been previously divided *. After unusual exertion, a period of repose seems necessary to enable a muscle to recover its full capability of acting upon excitement.

Sir A. Carlisle discovered, that in several animals, which are remarkable for the slowness of their muscular movements, the main artery of each limb is abruptly divided into numerous trunks, which pursue a parallel course and freely communicate. In the fore leg of the lemur tardigradus, as many as sixty brachial arteries are thus formed †. One effect of this

* Experimental Inquiry, p. 100.

† Phil. Trans., vol. c, p. 99.

provision must be to lessen the force of the blood circulating in the muscles of the limbs; but its relation to the habits and muscular power of the animal is unknown. In this, as in other instances, we are wholly unacquainted with the qualities in the organization of muscles, which diversify their mode of irritability.

The rigidity of muscles, which ensues soon after death, should tend to elucidate the nature of their action during life. The period at which this change begins, as well as its degree and the term of its continuance, are very indefinite, but appear to have some relation to the degree of physical exhaustion which the body has previously undergone. The muscles of those killed by lightning are said, but I believe erroneously, not to become rigid. In animals that have been hunted or driven hard before slaughtering, the muscles stiffen in a few minutes; but the rigidity is incomplete, and disappears sooner than in other cases.

In sheep and oxen the joints have ordinarily begun to stiffen in half an hour after death: in about twenty-four hours the rigidity appears complete, and the flesh when divided does not retract: but it seems that during the first three or four days it continues gradually to acquire more firmness. In hot weather the flesh of slaughtered animals never becomes perfectly rigid, and, till decomposition begins, retracts in some degree when divided. Warmth appears directly to prolong the phenomena of irritability in dead muscular parts. A heart that has ceased beating will even resume its action when immersed in warm water. It may be observed, that under circumstances nearly similar, like parts in different animals of the same species vary remarkably in respect to the duration of their irritability after death. In two cats destroyed by hanging, the heart of the one had entirely lost its irritability in half an hour; in the heart of the other the auricles continued, at the expiration of four hours, occasionally to contract. In one instance the voluntary muscles, in another the involuntary muscles, first lose the capacity of being excited by stimuli. If the surface of the flesh is exposed within a few minutes after death, the fibres are seen to describe a right line, unless their attachments be brought near to each other, when they lie in folds: after a minute or two, slight convulsive actions are to be remarked of the separate fibres, both in the heart, and in the muscles of the trunk

and limbs: these last for a few minutes, and are capable of being re-excited by sprinkling salt upon the surface. Rigidity is produced almost instantaneously if warm water is injected into the arteries of a muscle. The flesh under these circumstances becomes pale, increased in bulk, and suddenly hardens.

The operation of crimping fish consists in dividing the muscular fibre before it has become rigid, and then immersing it in spring water. A small part treated in this manner, contracts and hardens in five minutes; a larger part takes a longer period. Sir A. Carlisle observed, that crimped flesh gains both in weight and in specific gravity. Crimping only takes effect if performed before the natural stiffening has been completed. Sea-fish intended for crimping, are usually struck on the head when caught, which is said to preserve them for a longer period fit for the purpose. No doubt this expedient, which is fortunately merciful, operates by preventing the fish from exhausting its muscles in convulsive efforts.

The preceding details illustrate generally the nature of muscular action. A muscle is, it appears, so constituted, that upon a given impression certain points in each fibre are suddenly attracted towards each other with increased force. We have yet to learn whether the attraction is exerted equally by every integrant molecule of the fibre, or whether it operates from definite points at appreciable intervals. Either supposition appears compatible with the change already described from the right line to a zigzag, which is observed to take place when the fibre is shortened beyond certain limits.

Muscular parts are found to vary among themselves, as regards their natural condition in the absence of special impressions, the duration of their action and of the intervals of repose which they require, the kind of stimulus calculated to excite their action, and the degree of sensation attending their use.

When we seek for some broad and leading distinction among parts of this nature, a phenomenon presents itself, which serves to distribute the different varieties of muscular irritability under two heads. It is to be understood that every voluntary muscle receives a nerve, upon the division of which its action is paralized: nerves of this class are generally called voluntary nerves. Now I ascertained that after any voluntary nerve

whatsoever is cut through, either in a living animal or immediately after death, mechanical irritation of the part of the nerve disconnected with the brain, as for instance the pinching it with forceps, causes a single sudden action of the muscle or muscles it supplies. On the other hand, a like effect cannot be produced by irritating mechanically the nerves distributed to those muscles, over which the will has indisputably no influence. Yet it must be admitted that the phenomenon which I have described is not exclusively confined to those muscles which are allowed at all hands to be voluntary; nor in truth is it shown in all the muscles which seem at first sight to be directly under the control of the will. But it is not easy in various instances to determine whether muscular actions are voluntary or not; while the point of distinction, which is here proposed, has at all events the recommendation of being readily verifiable. Setting aside therefore in the first instance the question of the influence of the will, let us be satisfied with observing what muscles act when a divided nerve that enters their substance is mechanically irritated, and what do not; we may afterwards trace the collateral differences of the two classes of muscles, which are thus distinguished.

The parts which are susceptible of this mode of excitement, are the muscles of the trunk, head, and limbs, of the tongue, of the soft palate, of the larynx, of the pharynx and œsophagus, and of the lower outlet of the pelvis. The opposite class comprehends the heart, the stomach, the small and great intestines, and the bladder.

The collateral differences which characterize either class, are, with exceptions afterwards to be adverted to, the following.

Of the muscles, which act when a nerve distributed through them is mechanically irritated, it may be remarked;

1. That they admit of being thrown into action by an effort of the will.

2. That with sufficient attention and resolution, their action may be refrained from.

3. That their action is attended with a conscious effort, and is guided by sensation.

4. That if divided, the separate parts retract instantaneously to a certain distance, and subsequently undergo no further permanent shortening.

5. That when mechanically irritated, a single and momentary action of their fibres alone ensues.

6. That they remain relaxed, unless excited by special impressions, both in the living body and before the loss of irritability after death.

7. That their action in the living body habitually results from an influence transmitted from the brain or spinal cord through the nerves.

The exceptions to be made against this statement, if applied generally, are, that the three first affections are not easily brought home to the muscular fibres of the œsophagus, or of the lower part of the pharynx; but it deserves at the same time to be considered, that the lower part of the pharynx and œsophagus are in the peculiar situation of parts employed upon one object alone instinctively and habitually, on the recurrence of one impression; a condition which would soon reduce a strictly voluntary muscle to a state apparently removed from the control of the will.

Muscles of the preceding class, if we except the fasciculi belonging to the pharynx and œsophagus and urethra, are so disposed as to extend from one piece to another of the solid framework of the body: they enlarge or straiten the cavities of the trunk; they produce the phenomena of the voice; they close the excretory passages; the greater number are employed to move the limbs upon the trunk, the frame upon the ground. Muscles of the second class are used, like the exceptions in the preceding, as tunics to the hollow viscera, the cavities of which they diminish in their action, and thus serve to give motion to their contents. The œsophagus, indeed, appears to partake of the nature of both classes of muscles; when the nervi vagi are mechanically irritated one sudden action ensues in its fibres, and presently after, a second of a slower character may be observed to take place.

Of the muscles which do not act upon the mechanical irritation of any nerve distributed through them, it may be remarked;

1. That the will cannot instantaneously or directly produce action in them.

2. That the resolution to abstain from their action is insufficient to repress it.

3. That their action is not attended with a conscious effort, and seldom has reference to sensation.

4. That if divided, the retraction which follows is in most instances slow and gradual.

5. That if they are mechanically irritated, not one, but a series of actions, ensues.

6. That their natural state, in the absence of external impressions, is not continued relaxation. When the heart and bowels are removed from the body of an animal immediately after death, they continue for a time alternately to contract and to dilate.

7. That an impression transmitted through the nerves does not appear the usual stimulus to their action.

The exceptions to be found to these remarks are more numerous than in the preceding class, and their consideration would lead me into details unfitted for this part of the work, in which my object has been to convey a general notion only of muscular action. Let me conclude the present chapter by observing, that the leading distinction pointed out among different modes of irritability appears applicable to other textures, besides those which are strictly termed muscular. The irritable portion of the iris I found would in some animals contract instantaneously, upon the mechanical irritation of the third nerve. On the other hand, the calibre of arteries is not diminished when their nerves are pinched: and the uterus and the skin, it is probable, are equally insensible to this mode of excitement.

CHAPTER IV.

OF THE CIRCULATION OF THE BLOOD.

The stream of florid blood collected from the capillary vessels in the lungs, flows to every part of the body, and permeates the systemic capillaries. The stream of black blood collected from the systemic capillaries flows back to the lungs. The former passes through the left cavity of the heart, the latter through the right. The structure of the heart is muscular; its action gives motion to the blood, which through the operation of valves that preclude its retrograde course, flows uniformly in one direction. This great subject naturally divides itself into three parts; the first relating to the mechanism of the circulation; the second to the objects attained by the pulmonary circulation; the third to the purposes of the systemic circulation.

SECTION I.

Of the Mechanism of the Circulation.

The principal agent in the circulation of the blood is the heart. The arterial and venous trunks may be viewed as nearly passive; their influence in promoting or retarding the circulation will be considered afterwards.

In adult human beings the heart is a double organ, or it contains two cavities which do not communicate, and which, for any purpose answered in the adult œconomy, might as well have been disunited. Each cavity consists of two chambers, an auricle and a ventricle: the auricle is the thin muscular sac into which the blood is received immediately from the veins;

the ventricle is a strong muscular bag, into which the blood flows from the auricle, and out of which it is forcibly expelled into a single artery.

Each chamber is alternately contracted and expanded. The state of contraction is termed the systole, that of relaxation, the diastole of the chamber. The two auricles contract synchronously, and dilate synchronously. The two ventricles do the same: but the period of the action of the auricles and of the ventricles alternates: when the auricles contract, the ventricles are relaxed to receive the blood flowing into them from the former; at the time that the ventricles act, the auricles are relaxed to receive a new draught of blood from the veins.

The heart is of an oval figure, and should be about the size of the fist of the subject. The broad or auricular end, or base of the heart, is turned backwards and to the right, the apex forward and to the left. The septum of the heart which divides its cavities, is not disposed exactly in its long axis, but obliquely to it, so that the apex is formed of the left ventricle exclusively. The apex of the heart beats against the cartilage of the left fifth rib, or against the interval between the fifth and sixth. The flat under-surface of the heart rests upon the diaphragm, to which the heart is tied down by the reflected pericardium in such a manner as to fix and support it, without encroaching upon its freedom of motion; the base of the heart is immoveably fixed by the great vessels which stretch from it upwards and downwards and to either side.

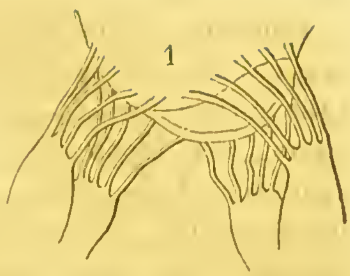
In studying the action of the heart we should begin with the ventricles, to which the action of the auricles is only subsidiary, and not necessary; and of the two ventricles we should take the left, from the mechanical completeness of its structure.

As soon as the ventricle has acted (if the heart is under inspection in the opened thorax of an animal) it is seen to expand again. This expansion is not a passive effect of blood being forced into it, but is an active force of dilatation in the muscular structure, as any one may easily ascertain, by observing the action of a turtle's heart that has been recently removed from the animal after decapitation. The empty ventricle, if grasped in the hand, may be felt to expand with considerable force. Now, as the vascular flesh of the body is soft, pliant, and compressible, it is evident that the blood it contains will be driven by the pressure of the atmosphere into

the ventricle, at the moment when the ventricle thus actively expands: the elasticity of the blood-vessels and the contraction of the auricle must co-operate with the atmospheric pressure in carrying the blood into the ventricle, at the period of the expansion of the latter. But all these forces tell in one direction only. They drive the blood from the auricle into the ventricle: they would indeed cause the blood with which the aorta has just been filled likewise to flow retrogradely into the ventricle, but for a specific provision. That provision consists in the semilunar or sigmoïdal valves of the aorta. The aortic valves are formed of three semilunar folds of membrane, that are attached by their convex edges to the entire circumference of the aortic opening. When the blood issues from the ventricles, they are thrown up and lie smoothly against the sides of the vessel, so as to offer no sensible impediment to the escape of the blood: as soon, however, as the ventricle has ceased to act, their fine edges are caught by the reflux of the blood, and forced down with mechanical precision and exactness, so as instantaneously and perfectly to close the opening into the ventricle.

When the ventricle therefore actively expands, it draws no refluent tide from the aorta which it has previously filled, but sucks from the auricle and veins that lead to it a fresh draught of blood. The quantity which is thus drawn into the ventricle at its diastole, is supposed to be from an ounce to an ounce and a half.

The ventricle being filled, its systole immediately follows with a sudden and jerking motion; the muscular fibres contract, and the contents of the chamber are expelled into the aorta, the valves of which are instantaneously thrown up and let them pass. But how is the blood prevented from passing backwards into the left auricle? The mitral valve is placed for this purpose at the auriculo-ventricular opening; it consists of a circular slip of membrane attached at one edge to the margin of the opening, the opposite edge being uneven, and lengthened into two processes of unequal lengths. In the free edge of the valve tendinous cords are attached, which join it to some prominent muscular fibres within the ventricle, which are called fleshy columns. The action of these fleshy columns, and of the tendinous cords in closing the valve, may be easily understood from the adjoined figures.



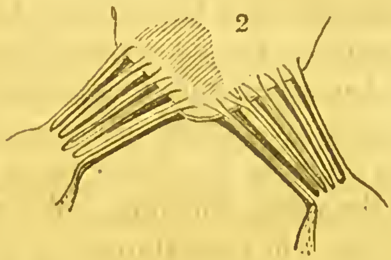


Figure 1 represents the mitral valve during the diastole of the ventricle, the fleshy columns relaxed, the chordæ tendineæ loose, the passage through the auricular valve patulous.

Figure 2 represents the condition of the valve during the ventricular systole: its edges are then drawn into contact, so as to form a kind of flattened conical projection into the ventricle. Two circumstances deserve to be noticed however, without which the mechanism would be inefficient. The first is, that each fleshy column receives all the tendinous cords of the adjacent sides of the points of the valve: through which it happens, that (as both figures show) the act of tightening the tendinous cords is capable of bringing the opposite parts of the edge of the valve into contact. The other circumstance is the following: to close the opening of the valve I found by trial, that it is not sufficient simply to draw upon the tendinous cords in a direction from the base of the heart towards the apex, but that the traction must be oblique; the tendinous cords must be drawn outwards as well as towards the apex of the heart. To what extent and by what means this effect takes place during life I was in doubt till the last autumn, when in assisting Dr. Hope in some experiments upon the action of the heart in an ass stupified with woorara, I observed that the left ventricle at its systole not merely shortened, but acquired a circular outline; it became broader while emptying itself: but its greatest breadth I noticed to be about the part at which the fleshy columns are situated. The fleshy columns are thus carried away from the axis of the ventricle during its systole, so that their action becomes oblique, corresponding with that, which, on making the trial in an opened heart after death, is found the proper direction to pull, in order to close the valve by means of the tendinous cords.

The action of the tricuspid valve takes place upon similar principles with that of the mitral; but the valve has three

points, sometimes more, instead of two, and a proportionate number of fleshy columns, and sets of tendinous cords; in their action these draw together the neighbouring sides of two adjacent points of the valve; but the effect is incomplete, and the tricuspid valve is never perfectly closed: it is not easy therefore to estimate the quantity of blood which is thrown at each systole into the pulmonary artery. Nor indeed can the quantity thrown into the aorta be accurately measured; all that lies upon the auricular side of the mitral valve must be thrown back into the auricle, and some more must be repelled before the valve is perfectly closed. The chambers of the right side generally appear something larger than those of the left, which probably has in part to do with the imperfectness of the tricuspid valve.

Two sensible phenomena go with the action of the heart; one, an impulse communicated to the left side of the chest, the second, certain sounds which accompany it.

The impulse communicated to the side of the chest has been variously accounted for. It is evidently the effect of the heart striking against the ribs: but how comes the heart to strike against the ribs? I made the observation, that when the heart of a large dog, yet acting, was placed upon a table, the apex was sensibly lifted up at each contraction of the empty ventricles. It is probable that the beating of the heart of a living person takes place in the same way. The apex of the heart is in part lifted upwards by the action of its spiral exterior fibres, in part thrust upwards by the under surface becoming from flat slightly convex. The sensible impulse against the chest of a living person is synchronous with the ventricular systole.

The sounds produced during the natural action of the heart are two, which bear the following relation in time to each other, and to the interval between two beats; when the pulse is sixty in a minute, the first sound lasts half a second, the second sound a quarter of a second, the interval the remaining quarter of a second. The first sound is duller and prolonged, the second smarter. The first sound corresponds with the systole of the ventricle, the second with its diastole. This was ascertained by experiments made by Dr. Hope, some of which I witnessed. The first sound is probably caused by the flapping to of the mitral valve, and the protracted vibration of the tendinous cords, the second by the flapping to of the sigmoïdal

valves. It was found by Dr. Hope, that the preventing either valve from closing, by wires passed into the heart, put an end to or impaired the sound attributed to the shutting of that valve.

The force with which the different chambers of the heart contract is not easily computed. But some experiments made by Dr. Hales throw considerable light upon this subject, and furnish us with an approximation to the average pressure upon the blood during the systole of the left ventricle. In some of the experiments of Dr. Hales, tubes were inserted into the arteries of living animals, and the height was observed to which the blood ascended in them. In a glass tube a sixth of an inch in diameter, fixed into the crural artery of a mare, the blood rose eight feet three inches above the level of the left ventricle of the heart; but it did not attain its full height at once: it rushed up about half way in an instant, and afterwards gradually at each pulse, twelve, eight, six, four, two, and sometimes one inch: when it was at its full height, it would rise and fall at and after each pulse two, three, or four inches, and sometimes it would fall twelve or fourteen inches, and have there for a time the same vibrations up and down, at and after each pulse, as it had when at its full height, to which it would rise again after forty or fifty pulses. When the glass tube was taken away, the greatest height of the jet of blood was not above two feet. Horses were found to expire when after continued hemorrhage the blood stood only at two feet in the tube. Upon a measurement of the area of the left ventricle, and comparing it with the height at which the blood stood in the tube in the preceding experiment, Dr. Hales concludes that the left ventricle of the horse exerts a force in propelling the blood equal to 113.22 pounds.

"If we suppose," observes Dr. Hales, "that the blood would rise $7\frac{1}{2}$ feet high in a tube fixed to the carotid artery of a man, and that the internal area of the left ventricle of the heart is equal to fifteen square inches, these multiplied into $7\frac{1}{2}$ feet, give 1350 cubic inches of blood, which press upon that ventricle when first it begins to contract, a weight equal to 51.5 pounds*."

The alternate action and relaxation of the muscular fibres of the heart appear not, like similar phenomena in the diaphragm

* Hæmastatics, p. 21 and 39.

or any other voluntary muscle to depend upon a series of impressions transmitted from the brain or spinal cord. I have ascertained, that in the heart taken from the body of an animal immediately after death,—if the blood be carefully washed from its internal surface,—or if the auricular part be separated from the ventricles by a clean section,—the alternate states of action and relaxation continue for a time to succeed each other in each part as before. For the brief period, during which it is reasonable to suppose that the heart retains its perfect chemical constitution, no stimulus seems required to excite it to contract. The alternation of action and repose I conclude therefore to be natural to its fibre, or to be the immediate result of its structure.

It is remarkable that if the heart yet beating is placed in warm water, it continues to act more briskly and for a longer time than if exposed to the air. On the other hand, if water is injected into its vessels, the flesh of the heart becomes pale and swollen, and after two or three beats hardens permanently. If the fibres of the heart are transversely cut through, their action is stopped at once.

In the first of the preceding instances the heart is subjected to some of the conditions, under which it exists in the living body. With a little contrivance, every influence to which it is subjected during life, excepting that derived from the nervous system, may for a short space after death be kept up upon the heart. The researches of Mr. Brodie have successfully elucidated the phenomena which ensue upon sustaining in dead animals an artificial respiration, extending to some very curious results presently to be noticed respecting secretion and the source of animal heat, the original experiment of Vesalius and of Hooke. If the chest be alternately inflated with and emptied of atmospheric air, the blood which passes through the lungs acquires a florid hue; the heart's action does not sink as when black blood is contained in both its cavities; and a complete circulation of the blood may thus be preserved for the period of two hours and a half after death. Under other circumstances the heart's action ceases in from five to ten minutes after apparent death. The preceding phenomena were observed when the head had been removed after tying the vessels in the neck. Dr. Wilson Philip found, that in warm-blooded animals the circulation might be kept up after death by means of artificial respiration equally well, whether the brain and spinal cord

had been left or removed; and that in frogs that function spontaneously continues for a considerable period after the same degree of mutilation*. Molæ again are occasionally developed in the uterus, which have neither brain nor spinal marrow, in which, nevertheless, a circulation has existed.

But while the fact appears thus established, that the heart needs no specific irritation through the nerves to cause it to contract, it must not be lost sight of, that the brain and spinal cord influence remarkably the frequency and vigour of its action. How promptly mental emotions affect the heart is too familiarly known to need illustration. The effect of physical impressions upon the brain and spinal cord is not less decided. The experiments of Le Gallois and Dr. Wilson Philip sufficiently prove this assertion. When spirit of wine, in the experiments of Dr. Wilson Philip, was applied to the surface of the brain in a stunned rabbit, or to the cervical or dorsal part of the spinal cord, the heart was observed to beat more quickly than before; this effect, however, gradually subsided, and the heart beat again as at first. When an infusion of opium was employed, the heart's action was found to be at first rendered stronger; it then became enfeebled; but on washing off the poison the heart recovered itself. On a large portion of the brain or spinal cord in a rabbit being suddenly crushed with a steel instrument, the heart's action was observed to be immediately enfeebled, if not stopped entirely. On the brain of a frog being crushed, the heart was observed to perform a few quick and weak contractions; it then became quite still for about half a minute: after this its beating returned, at first imperfectly, but in ten minutes afterwards it was sufficiently restored to support the circulation, but with less force than before the destruction of the brain. The spinal cord was then crushed at one blow; the heart again beat quickly and feebly for a few seconds, and then seemed entirely to have lost its power of acting. Dr. Wilson Philip remarked that the heart's action in these experiments was rendered quicker or slower, stronger or more feeble, but never rendered irregular†.

The heart in adults beats in general from seventy to seventy-five times in a minute; in infants of two years of age a hun-

* Phil. Trans. vol. ci, p. 39.

† Experimental Inquiries, p. 36.

dred to a hundred and ten times; in infants of one year a hundred and twenty times; at birth a hundred and forty times: at puberty about eighty times; towards old age the heart acts at longer intervals, and the pulse does not exceed sixty in a minute.

During health the contractions of the ventricles generally take place at equal intervals, and with the same degree of force, or in other words are regular and equable. But there are some persons, in whom, when in perfect health, the pulse is habitually irregular; and only regular when they labour under febrile excitement.

The quantity of blood in the body of an adult is estimated on an average at from thirty to forty pounds: between one and two ounces are supposed to be propelled at each contraction of the left ventricle into the aorta, with a velocity of one hundred and twenty feet in a minute; and as the contraction of the ventricle occupies a third only of the period from one systole to another, the mean velocity of the blood in the aorta may be computed at eight inches in a second*.

The force, with which the blood is propelled, appears employed in overcoming the friction of the innumerable capillary tubes which it traverses. In the capacious venous trunks the blood moves slowly onwards in an equable stream, and with an impulse so moderate, as to rise in a vertical tube, according to the experiments of Hales upon the horse, to the height of six inches only. In the smallest arteries the flow of the blood *per saltum* appears to be lost,—a phenomenon which is included under the following general proposition in mechanics, that an intermittent motion may be changed into a continuous motion by employing the force, which produces it, to compress a spring, the reaction of which is constant†.

We may next inquire into the properties and uses of the arteries and veins. An artery is a cylindrical tube of great elasticity; its texture is separable into, 1. An inner serous coat: 2. A middle fibrous coat, of a yellow colour in the larger trunks, of a redder hue in the smaller branches, composed of fibres, which are disposed transversely, but seem in some degree interwoven; they are very elastic, and at the same time so

* Young's Medical Literature, p. 609.

† Magendie, Elémens de Physiologie, tome ii, p. 388.

brittle, that the pressure of a ligature tied upon an artery cuts through the fibrous together with the inner coat: and, 3. An outer cellular coat, consisting of tough white elastic fibres closely interwoven, which the pressure of a ligature does not divide. Dr. Hales ascertained that the force required for bursting one of the carotids of a dog, is equal to that of a column of water one hundred and ninety feet high. He does not remark that the artery became dilated, but observes that with this pressure the artery burst at once.

A vein is a flexible tube of great strength, very elastic within certain limits, consisting of an inner serous tunic, and a dense external coat of white and closely interwoven fibres. The inner coat is thrown at intervals into semilunar folds that occur in pairs, and are attached by their convex margins each to half the circumference of a vein: as the blood flows towards the heart, these valves lie against the sides of the vessel; upon its reflux they are thrown down and their edges meet. Valves are not found in the venæ cavæ or in the veins of the abdominal viscera: they are found in the iliac veins, in the veins of the neck and head, and of the extremities, and in the pulmonary veins. Dr. Hales found the jugular vein of a mare to burst with a force equal to that of a column of water one hundred and forty-four feet high *.

When an artery divides, the two branches have a common area larger than that of the trunk, and in most instances diverge at an acute angle; the same is observed of veins. The arterial and venous trunks generally are distributed together: the largest arteries have one accompanying vein, the smaller arteries two. In the neck and extremities superficial venous trunks are found besides those which accompany the arteries. The area of the venous system is greater than that of the arterial, in the proportion of four to one, according to Borelli. The ratio between the capacity of individual arteries and veins in different parts, varies: between the carotid and internal jugular 196 : 441, between the subclavian artery and vein 81 : 196, between the crural artery and vein 3844 : 7396, between the aorta and vena cava 9 : 16, between the splenic artery and vein 156 : 676†.

* Hæmastatics, p. 151.

† Haller, Elementa Physiologiæ, vol. i, p. 131.

Arteries and veins have their vasa vasorum, and are supplied with nerves derived from the sympathetic, the nervi vagi, and the spinal nerves, if not indiscriminately from all but the first, second, third, and fourth, and the soft portion of the seventh.

Little is known of the nature of the capillaries : their existence even is only a matter of inference ; the particles of the blood are seen in transparent parts of animals to move constantly in the same tracks, which are supposed to be canals of a similar nature to the arteries. These canals are certainly capable of enlarging, and of admitting more blood at one time than at another. If an irritant, as for instance diluted liquor ammoniæ, is applied to the web of the frog's foot, the small vessels speedily become dilated, the blood flows more slowly through them, and here and there its course is entirely arrested : bathed with cold water, the part slowly recovers itself, and the vessels contract. A particle of dust resting within the eyelids produces in a few seconds an appearance of a fine vascular network upon the white part of the eye ; it is supposed that this results from the sudden enlargement of vessels, which were before too minute to admit the coloured particles.

But more is known by direct observation of the properties of the larger arteries, and the phenomena of the capillary circulation are only to be explained by reasoning upon analogy.

The first phenomenon which attracts attention in the larger arteries of the body, is their sensible pulsation ; it is synchronous with the action of the left ventricle, and results from the impulse communicated by the fresh jet of blood from the heart. The velocity of a pulsation, according to Dr. Young, is sixteen feet in a second * ; and consistently with this estimate, the throb of the arteries appears to be simultaneous in every part.

In a curved artery, as for instance in the temporal, the pulse is *visible ;* the artery is sensibly elongated at each systole of the left ventricle, and moved from its place, to which it returns during the succeeding diastole. But if a straight artery be examined, as for instance the common carotid, when laid bare in the neck of an ass, no motion whatever or change of figure is distinguishable, as long as the animal lies quiet and undisturbed. And in order even to feel the pulse, it is necessary,

* Young's Medical Literature, p. 605.

as Dr. Parry observed, to compress with the finger the artery, so as slightly to obstruct the rush of blood.

M. Magendie mentions, however, that the aorta is visibly dilated at each systole of the left ventricle, and that the same change may be shown in the crural artery by the following experiment. If a ligature be passed behind the crural artery and vein round the thigh of a dog, and drawn tight, so that the circulation be sustained through the two crural vessels alone, upon compressing the artery between the finger and thumb, it gradually contracts on the side remote from the heart; but upon removing the finger and thumb, the artery, according to M. Magendie, while becoming distended to its former dimension, at each pulse is visibly dilated.

The preceding appearances in arteries admit perhaps of being referred to the acknowledged elasticity of their textures. But on other occasions partial changes are observed in the calibre of arteries, while the pressure of the circulation is equal upon every part, which seem to result from another principle, which can be produced by blind physiological experiments, and occur in the order of nature for definite and important objects.

Mr. Hunter observed, that when a large artery, as for instance the crural artery of a dog, is exposed for some time to the air, its diameter becomes gradually diminished. Dr. Parry observed further, that if a ligature is placed upon an exposed artery so as merely to lie in contact with its surface without the knot being drawn, the vessel contracts where the foreign body touches it, but preserves its full size upon either side of the ligature. When a portion of an artery is removed from a living animal, it slowly contracts during the first minute or two to less than half its first diameter.

By the experiments which have been mentioned, arterial contraction is produced. The following method I discovered would cause the partial dilatation of an artery. If a large artery in the living body, as for instance the carotid in an ass, or the crural artery of a dog, be rubbed for half a minute between the finger and thumb, its diameter at the part so treated becomes sensibly increased. The ampullated appearance thus produced upon the artery subsides in a quarter of an hour if the wound is closed. If before it has again contracted, the ampullated part is removed and examined, the

enlargement of the vessel is clearly seen to be dilatation, not thickening.

Hemorrhage from a small artery, that has been divided, becomes slackened in a short time; and before it can be supposed that faintness and a languor of the circulation can have taken place. This spontaneous cessation of arterial hemorrhage seems to occur more readily in animals than in human beings. If in an experiment upon a horse or ass a muscular artery of the size of a crow-quill is divided, and the subsequent changes are watched, the jet of blood is seen to gradually diminish in volume, and the distance to which it is projected to become less and less; at length the blood merely trickles over the adjoining surface, then but slightly oozes, then stops. These phenomena distinctly result from the contraction of the extremity of the divided artery. Cold, which has so remarkable an effect in producing contraction of the skin, contributes to arrest hemorrhage. Warmth and moisture, which relax the skin, encourage the continuance of hemorrhage.

When the main artery is tied in a part, the blood finds its way more freely than before through collateral vessels, which speedily become dilated. If the facts which have been already mentioned are sufficient to show that arteries in warm-blooded animals are irritable parts, it is easy to account for *this* phenomenon. We have but to suppose that the tone of the collateral vessels is lowered on this occasion: their usual resistance to the force of the blood being thus diminished, they yield and are dilated by it.

The vascular turgescence of various parts is found to be sometimes disproportionately increased during perfect health. The class of phenomena, to which I advert, are said to result from local action. The following is an instance. The uterus and ovaria in a rabbit, killed when the animal is hot, are found to be turgid and black with blood; if injected in this state with size and vermilion, they are rendered much redder than usual. The vessels have become enlarged and admit more of the colouring matter than they before would have done. The suffusion of the countenance in blushing is a phenomenon of the same nature with the preceding. The simplest explanation of both is to suppose the vessels irritable parts, the tone of which is lowered, or which are relaxed when a larger draught

of blood is required in any part. The opposite hypothesis, that a sudden constriction at any part of the capillary system is the cause of the dilatation of the vessels on the side next the ventricle, may be considered untenable, since it is opposed to analogy. When a large artery is tied, it does not become more capacious on the side next the heart.

The opinion, which I advocate, that the flow of blood in increased quantity to a part results from the relaxation of the coats of its small arteries, is remarkably confirmed by what is noticed respecting the larger vessels, wherever local action frequently occurs, or happens to exist for a considerable period. The arteries of such parts gradually become elongated and tortuous. This is the character of the arteries of the testis, of the uterus, of the mammæ towards the latter period of and after utero-gestation, of the face and temples. The latter instance, perhaps, requires an explanation to show its coincidence with the three former. In a child the temporal arteries are straight; in proportion as life advances they become more and more tortuous; but as life has advanced, the sources of passion and excitement have multiplied, and the face has often flushed and burnt, and the temples throbbed with an increased flow of blood. Let me endeavour to show in what manner the tortuous form, which arteries acquire in such cases, may be explained, so as to be consistent with and to support the theory of local action which I have adopted.

We may presume that an artery, at the average tone of arteries, would be affected in the same manner by an unusually forcible contraction of the left ventricle, as a relaxed artery by the ordinary pressure of the blood. The former case is easily obtained. It has been already mentioned, that the carotid artery laid bare in the neck of an ass lies without any visible pulse or change, as soon as the animal becomes composed. But if the animal be then alarmed, as by holding its nostrils for a few seconds, the heart acts violently, and the carotid artery leaps from its place, and becomes elongated and tortuous at each stroke of the ventricle. It follows, that if the coats of the same vessel were specially relaxed, a like phenomenon would ensue during the ordinary action of the heart.

It appears, therefore, that the phenomena of local action, whether in large or in small arteries, may be accounted for, by assuming as their common cause, a spontaneous relaxation of

the coats of these vessels, followed, if the local action* persists, by enlargement through growth. But where local action exists, the veins likewise become enlarged and tortuous. To what principle is this change to be referred?

It is not likely that veins are irritable; the effect of their valves, which act by their mechanical adjustment to a given area, would be defeated were that area readily capable of enlargement. They probably become dilated through growth alone, caused by distension.

What are termed varicose veins are tortuous and dilated veins. They are frequently observed below the integuments of the thigh and leg. No doubt is entertained that the veins of the leg often become varicose through the pressure of the column of blood in the descending cava, which by a gradual process of dilatation renders each pair of valves in succession useless. The same pressure, which gradually dilates the veins, naturally tends to elongate them. Pressure, then, upon the inner surface of a vein, tends to enlarge and elongate it.

Varicose veins of the legs are again produced by ligatures tied below the knee; the superficial veins are in this instance observed to be continually swollen, and gradually to become tortuous, as if knotted. The swollen state of the veins shows the internal pressure to which they are subjected: but this internal pressure is the force of the blood propelled from the left ventricle.

Now by my hypothesis, the blood during local action would arrive in the veins through larger channels than before; its force therefore would be less broken; its pressure would be increased upon the veins. But increased pressure upon the inner surface of the veins has just been shown to enlarge and elongate them; and thus the state of the veins in parts subject to local action tends to support the theory which I have advanced.

Blood is not returned to the heart so readily from a dependent part, as from parts whence it has to descend. The circulation in the lower extremities always appears more sluggish than in the upper part of the body. If the hand be held up, it becomes whiter and less in bulk; if it hang down, it becomes swollen and darker. In the one case the weight of

* I am aware of the solecism of calling that process local *action*, which I represent as commencing with *relaxation*.

the blood favours its return by the veins to the heart; in the other case its weight is opposed to its ascent along the veins. The veins of the lower extremities have coats as thick as those of arteries: the arteries are perfectly straight, in order that there may be no unnecessary waste of the impulse derived from the heart.

The arteries distributed to the human brain are four in number, the two internal carotids and the two vertebrals. The brain is an organ of so slight and delicate a texture, as to suffer more readily than any other from an unusual force of the blood in the arteries, or from its accumulation in the veins. Accordingly in some animals, as for instance in the common ox, the internal carotid artery, upon entering the skull, divides into many branches, which subsequently reunite and form a trunk, in which the force of the blood must be greatly diminished. This contrivance is termed the *rete mirabile.*

In human beings another provision is employed for the same purpose. Each of the four arteries of the brain is bent twice in an abrupt curve, just before or after entering the cranium: and as a proof how sufficient this contrivance must be to break the rush of blood upon the brain, the arteries distributed to that viscus are found to have thinner and weaker coats than other arteries of the same calibre.

Some physiologists have confounded the original and permanent curvatures of the cerebral arteries with the superinduced curvatures of the temporals, and suppose the cause and purpose of the two phenomena to be the same. The preceding remarks will have led the reader to view these phenomena as utterly and essentially dissimilar.

The veins of the brain, instead of being collected into large trunks of the ordinary description, open into cylindrical or triangular canals in the dura mater, of great strength and thickness, which are termed sinuses, and terminate after circuitous routes in the internal jugular vein of either side. The oblique entrance of the veins of the brain into the sinuses, the undilatable nature of the latter, their long and winding course, are circumstances that tend to prevent the reflux of venous blood upon the brain, when its entrance into the chest is impeded.

Two phenomena yet remain to be adverted to. One is the emptiness of the arteries after death, the other the influence of breathing on the circulation.

The interesting experiments of Dr. Carson went to show, that the resiliency of the lungs is perpetually operating to suck the blood into the thorax, pumping out the systemic vessels. Dr. Carson supposed that the emptiness of the arteries after death is owing to the draught of blood to the right side of the heart through this cause. But there is reason to think that Dr. Carson over-estimated the influence of this force. Mr. W. Robinson, who has repeated some of Dr. Carson's experiments, informs me that he has not found the distribution of the blood in the veins and arteries equalized by excluding the agency of the resiliency of the lungs. The emptiness of the arteries after death is probably rather owing to their contraction on life ceasing, and subsequent relaxation; in part, perhaps, to their contents transuding.

The influence of the dilatation of the thorax during inspiration on the circulation of the blood was placed in a strong light by the experiments of Sir David Barry. One of these experiments consisted in tying the jugular vein of a horse, and inserting into the vein on the side open towards the heart, a flexible tube communicating with a spiral tube of glass, which stood in a vessel of coloured water. Each time that the animal inspired, the fluid was seen to ascend in the spiral tube *.

But other phenomena, several of which with their true explanation have long been familiar to physiologists, satisfactorily illustrate the same principle, and show that the influence of the state of the thorax upon the circulation is felt at every part of the system. During expiration, or in other words when the internal area of the thorax is undergoing contraction, the flow of the blood into the chest is shown to be retarded by the swelling of the superficial veins of the neck. Under the same circumstances, the brain, when an opening has been made in the cranium, is observed to be lifted up by the blood accumulating in it. Through the same principle, blood flows in a stronger gush from a divided artery during expiration, or even from a vein that after having been tied is punctured on the side remote from the heart †. During inspiration, on the other hand, the phenomena referred to are found to be exactly reversed; the suction towards the chest upon the vascular

* Recherches Experimentales, par D. Barry, M.D. p. 19.

† Magendie, Elémens de Physiologie, tome ii, p. 423.

system is indeed so strong at this period, that it has happened, that where the jugular vein has been opened in an operation and not secured, air has been inspired through the vein into the heart in sufficient quantity to destroy life.

SECTION II.

Of the Pulmonary Circulation.

The blood probably suffers some chemical change at every instant in every part of the vascular system; but with this difference, that in the trunks and branches the alteration is probably strictly internal, like that which wine undergoes in a corked bottle: but in the capillaries the composition of the blood is further modified by the perpetual addition and subtraction of ingredients that are introduced into it from without, and expelled from it, that is to say, by currents through the coats of the capillaries both inwards and outwards, or by imbibition and by exhalation.

Each lung is a tissue of air-cells, into the separate groups of which that form its lobules, a terminal branch of the wind-pipe opens. Or the trachea divides first into the two bronchi; the bronchus of each lung divides into a branch for each of its lobes: and after repeated subdivisions, these end in clusters of cells. Upon these cells the capillaries of the pulmonary artery are distributed.

If a lung is inflated and dried, its substance when divided, independently of the arteries and veins and bronchial tubes cut through, appears uniformly porous. The pores are shallow cups, being segments of air-cells. The air-cells are smaller, as M. Magendie observed, in infants than in adults, in adults than in persons advanced in age. In the lungs from a body about five years of age, I found the air-cells vary in size, but on an average to be $\frac{1}{100}$ of an inch in diameter, and to be nearly circular. In the lungs from a body about fifty years of age, their form seemed not to be as regular or uniform as in the preceding instance: their diameter varied from $\frac{1}{50}$ to $\frac{1}{70}$ of an inch. The extent of the internal surface of the lungs is less in proportion as the air-cells are larger.

The pulmonary artery divides into a branch to each lung, which subdivides into branches for each lobe, and for each

lobule. These vessels are accompanied by similar ramifications of the pulmonary veins. In the root of each lung the artery extends transversely outwards, the veins being situated before and below it. The bronchus descends obliquely behind the blood-vessels. If coloured water be thrown into the pulmonary artery, it passes into the pulmonary veins, but in part escapes into the air passages.

Each lung receives for its nourishment two or three vessels from the aorta, termed bronchial arteries, which are distributed with the bronchi. The pulmonary nerves are principally derived from the nervi vagi, which pass behind the root of each lung, and throw a plexus of branches round it: in part they are derived from the sympathetic. The lymphatic vessels from the substance and superficies of the lungs are received into a vast number of conglobate glands that are disposed around the bronchi and the bifurcation of the trachea. They are remarkable for the black colour, which they begin to assume in childhood, and which increases, though not uniformly, with age. The lung itself, of a pink colour in infancy, gradually becomes in like manner mottled with black. The experiments of Dr. Pearson on the nature of the colouring matter seem to prove that it is carbonaceous *.

Through the windpipe atmospheric air finds its way into the cells of the lungs: it is first inhaled the instant after birth, and is continually being expelled and replaced by fresh draughts through the operation of muscles, which alternately expand and contract the cavity of the chest, as long as life remains. If the lungs were inextensible and of a sufficiently firm texture, and the muscles which enlarge the chest were to act with unlimited force, no air would enter the lungs at each attempt to inspire, but a vacuum would be formed between the pleura pulmonalis and pleura reflexa. As, however, the lungs are readily extensible, atmospheric air rushes into and dilates their cells in exact proportion to the expansion of the area of the chest, and holds the two surfaces of the serous membrane in strict contact:—yet the same points are not always in apposition: when the chest enlarges, the surface of the lung during its expansion slides upon the pleura reflexa, as is shown by the elongation of the shreds of lymph by which the two layers of pleura are often found joined together after inflammation.

* Phil. Trans. vol. ciii, p. 166.

The passage of air into the lungs is so free, that the muscles which dilate the chest are not opposed by the atmospheric pressure in a greater degree than those which move the limbs; but they have to overcome the resiliency of the lungs, the elasticity of the abdominal parietes, and the resistance of the joints of the ribs, which all favour the state of expiration.

The term breathing or respiration is employed to signify both the mechanical operation of renewing the air within the lungs, and the changes to which its presence there contributes.

The mechanical construction of the chest, through which it admits of being alternately enlarged and diminished, will be subsequently described; every provision which it contains is employed in a greater or less degree at every repetition of breathing. The difference between a moderate and a deep inspiration is in the extent only to which the diaphragm and the muscles that elevate the ribs contract. But it may be observed, that for the fullest enlargement of the chest, the scapula and clavicle are raised and carried backward by the trapezius, levator scapulæ, and rhomboïd muscles, so as to give greater effect to the action of the serratus magnus and pectoralis minor; and that to yield a freer passage to the air, the nostrils are dilated, the larynx descends, and the rima glottidis is enlarged. Ordinary breathing takes place between the limits of forced inspiration on the one hand, and forced expiration on the other.

Numerous experiments have been made to ascertain the quantity of air alternately drawn into and thrown out of the chest, in ordinary breathing. Those of Dr. Menzies, which coincide nearly in their result with the researches of Jurin and Fontana, are commonly esteemed deserving of credit; but they differ remarkably from the observations of Sir H. Davy and of Messrs. Allen and Pepys. Differences in the relative size of the thorax in different persons, a difference in the frequency with which breathing is performed, and perhaps other causes, may have combined to produce this discrepancy. The frequency of respiration ranges between fourteen and twenty-seven times in a minute, but is commonly from seventeen to twenty.

Dr. Menzies employed two processes in estimating the quan-

tity of an ordinary inspiration. A healthy man five feet eight inches in height, and somewhat more than three feet about the chest, stood immersed in warm water to above his breast, in a vessel which narrowing at the upper part allowed an accurate estimate to be made of the level to which the water alternately rose and fell while he breathed. His pulse, both before and after immersion, beat sixty-four or sixty-five times, and his respirations were fourteen or fourteen and a half in the space of a minute; and they continued the same during two hours and upwards that he remained in the vessel without suffering inconvenience. The quantity of air thrown out at each expiration averaged at 46.76 cubic inches. The same person afterwards was employed to fill a cow's allantoïd, a membranous sac well calculated for such a purpose, by repeated expirations. The allantoïd was found to contain 2700 cubic inches of air, and was filled in many trials with fifty-eight expirations, which gives 46.55 cubic inches as the quantity of air expired each time. The same trials repeated upon a man five feet and an inch in height, whose pulse beat seventy-two, and the number of whose respirations was eighteen in a minute, gave from thirty-eight to forty cubic inches as the measure of a common expiration. Repeating the experiment himself, Dr. Menzies filled an allantoïd containing 2400 cubic inches by about fifty-six expirations, giving 42.8 cubic inches as the average quantity of each; and found that he exhausted the allantoïd, when previously filled by atmospheric air, by an equal number of inspirations *. Sir H. Davy estimates the quantity of a single inspiration at thirteen or seventeen cubic inches: Messrs. Allen and Pepys at sixteen and a half; Mr. Kite at seventeen; Mr. Abernethy at twelve.

Dr. Menzies observed that many individuals were capable by a forced expiration of throwing out an additional seventy cubic inches; and that the difference between an extreme inspiration and an extreme expiration often exceeded two hundred cubic inches. The lungs after death under ordinary circumstances are probably reduced to the same compass as by a forced expiration during life. Messrs. Allen and Pepys found that the lungs of a stout man about five feet eight inches high

* Menzies on Respiration, p. 21 et seq.

after death contained nearly one hundred cubic inches of air. Of this quantity 31.58 cubic inches were expelled by the resilience of the lungs upon opening the thorax *.

Dr. Bostock estimates the quantity of air, which may be voluntarily expelled from the lungs after an ordinary expiration, at 160 or 170 cubic inches, from trials made upon himself and others. Adding to this quantity 120 cubic inches for the residual air in the lungs, he supposes 290 cubic inches to be the entire contents of the lungs in their natural state, to which about forty cubic inches more are added by an ordinary inspiration. According to this calculation, one-eighth of the whole contents of the lungs is changed by each respiration †.

Atmospheric air consists of seventy-nine parts of nitrogen and twenty-one of oxygen. A small proportion of both elements, which has been variously estimated ‡, is found to have disappeared at each expiration: but this phenomenon loses interest when compared with the curious circumstance, that a disproportionate quantity of oxygen has disappeared, and has been nearly or completely replaced by carbonic acid. In the elaborate experiments of Messrs. Allen and Pepys, from 8 to 8.5 per cent. of carbonic acid were observed to be produced by each respiration. When the breathing was more rapid than usual, a larger quantity of carbonic acid was emitted in a given time, but the proportion at each expiration remained the same. The proportions of carbonic acid in the first and last portions emitted after a deep inspiration differed as widely as from 3.5 to 9.5 per cent. On an average it appeared that about 27.5 cubic inches of carbonic acid are produced per minute, or 39534 in twenty-four hours; a quantity which contains about eleven ounces troy of solid carbon §.

If a series of experiments conducted with great skill and caution, and leading to a theory the most simple, were sufficient to decide a question in physiology, the researches of Messrs. Allen and Pepys would set at rest every doubt respecting the changes produced in the air and upon the blood in breathing. They go to establish the facts, that in respiration the nitrogen

* Phil. Trans. vol. xcix, p. 411.

† Bostock's Elements of Physiology, vol. ii, p. 34.

‡ By Sir H. Davy at $\frac{1}{10}$ to $\frac{1}{100}$. Researches, &c., p. 131.

§ Phil Trans. vol. xcviii, p. 277.

of atmospheric air remains unaltered, and that the carbonic acid produced exactly equals the volume of oxygen which disappears. But by former experiments Messrs. Allen and Pepys had ascertained, that in the formation of a given volume of carbonic acid during combustion an equal volume of oxygen is consumed: and it is admitted that the change wrought upon the blood in the pulmonary circulation is apparently no more than might result from the abstraction of carbon. Thus the essential chemical phenomena of respiration appear to be comprised in the simple statement, that in the lungs the oxygen of the atmosphere combines with carbon (which is in some manner separated from the blood), forming with it carbonic acid.

Facts are not wanting to illustrate every step of the supposed process. Plants as well as animals deteriorate atmospheric air by substituting carbonic acid for oxygen; and it has been proved by the experiments of M. Huber and of Mr. Ellis, that when a plant growing in a closed vessel has consumed all the oxygen of the atmospheric air which it contained, the nitrogen, which remains undiminished in quantity, becomes carburetted; as if carbon spontaneously separated from the living body in a form fitted to combine with either element of the atmosphere, and in the absence of oxygen might for a time continue to be eliminated and to unite with another principle.

But it is evident that the preceding theory rests upon the position that the carbonic acid produced in breathing exactly equals the volume of oxygen lost. Now although this position be supported by the able researches of Messrs. Allen and Pepys, and has been advocated by Mr. Ellis, M. Magendie, and others, it cannot be admitted to be universally true.

In the experiments of Lavoisier and Seguin, the proportion of oxygen consumed exceeded that necessary for the production of carbonic acid in the ratio of about 100 to 81.5; a result which exactly coincides with the observations of Sir H. Davy. In the recent experiments of Dr. Edwards, in which small animals were immersed for a definite period in large quantities of air, the general fact of the surplus quantity of oxygen lost is abundantly proved: at the same time the apparently conflicting opinions of preceding physiologists are reconciled by the essential variableness of the results, which the experiments alluded to exhibit. Dr. Edwards's general conclusion is, that the excess of oxygen consumed in breathing

above the volume of carbonic acid produced, varies from nearly one-third of the oxygen that disappears to almost nothing; that the variation depends upon the species of the animal employed, upon its age, or some peculiarity in its constitution; and also that it varies considerably in the same individual at different times *.

Upon these grounds we must adopt a different theory of respiration. Part of the oxygen that disappears we must suppose to be absorbed in the lungs, and the rest may combine with the carbon of the blood to form carbonic acid; or the whole may be absorbed, and the expired carbonic acid may be a new secretion. Dr. Edwards adopts the latter opinion, and supports it by the following curious facts. If frogs during the month of March are confined for the period of eight hours in pure hydrogen after the previous exhaustion of their lungs by pressure, they continue to breathe, although less and less vigorously, till near the close of the experiment, during which a volume of carbonic acid nearly equal to the bulk of the animal employed is given out. A similar result ensued in experiments upon kittens. The young of many species of warm-blooded animals can exist for some time after birth without the contact of air: after two or three minutes, voluntary motion ceases: but from time to time deep inspirations are drawn, accompanied with yawnings and movements of the whole trunk. A kitten three or four days old was placed in a receiver containing pure hydrogen, and performed in nineteen minutes about as many inspirations. Upon examining the air in which the animal had been immersed, it was found to contain twelve times as much carbonic acid as could be accounted for by the residual air in the lungs at the beginning of the experiment †.

Dr. Edwards further found, that the quantity of carbonic acid, produced by frogs breathing in hydrogen during eight hours, is equal to that furnished in twenty-four hours by frogs immersed in atmospheric air: a curious result, which seems to show that

* De l'Influence des Agens Physiques, &c., p. 418. See likewise Dr. Bostock's remarks upon this subject; Elements of Physiology, vol. ii, p. 97 and 110. He concludes that a man under ordinary circumstances consumes about 45000 cubic inches of oxygen, and produces about 40000 cubic inches of carbonic acid in the space of twenty-four hours.

† De l'Influence, &c., p. 456 et seq.

the principles of the atmospheric air have possibly no influence, direct or indirect, upon the separation of carbonic acid.

The experiments of Dr. Edwards have thrown light upon another question, upon which opposite opinions have been entertained. M. Cuvier and Sir H. Davy have maintained that a portion of nitrogen is absorbed during respiration. Jurine, on the contrary, was induced to conclude, from the results of his experiments, that nitrogen is generated by respiration: and similar results were obtained by Berthollet and Nysten*. Dr. Edwards found, by immersing small animals in a large quantity of air for a limited period, that in many instances there was an evident increase in the quantity of nitrogen, while in others there was a loss of it. He observed, that the former change took place when the experiment was performed in spring and summer, or when young animals were employed, while the latter result was obtained when the circumstances of the experiment were reversed.

The production of carbonic acid varies in the same person at different times: Lavoisier found it greatly increased by exercise and during digestion: Dr. Prout observed it to be increased and diminished periodically. The maximum, estimated as equal to 4.1 per cent. of the oxygen inspired, occurred about noon: the minimum, equal to 3.3 per cent., occurred towards eight in the evening; from which time till half past three in the morning there was no change.

It is evident, that when we view the carbonic acid of expiration, as directly thrown off by the blood, it must be classed as a secretion. If so, it forms a remarkable instance of a secretion that can be made to take place [through artificial respiration] after death.

Atmospheric air is probably the only gas which can be breathed for an indefinite period with impunity. But other gases, as a mixture of oxygen with hydrogen in the proportions of atmospheric air, or nitrous oxide, or oxygen, may be breathed for a time without producing mischief. When oxygen nearly pure is breathed, the air expired, according to Messrs. Allen and Pepys, contains above 10 per cent. of carbonic acid: a proportion of nitrogen likewise makes its appearance in the room of an equal bulk of oxygen. In some recent experiments by Mr. Broughton the proportion of carbonic acid formed by

* Bostock, l. c. p. 105.

animals immersed in jars of oxygen appeared to be smaller. At the same time some very interesting observations were made upon the poisonous effects of the long continued breathing of this gas. After a period extending from one hour to four or five, rabbits and young cats and dogs began to breathe quick and pant, the heart acting violently. They then fell into a state of debility, and became insensible: the diaphragm then gradually ceased to act: but the heart continued to act strongly for some time afterwards. Some of the stronger animals, after having become insensible, recovered when restored to the atmosphere. In those which were opened, the blood was found equally bright and crimson everywhere, in the veins, the heart, the arteries.

Other gases, as carburetted hydrogen, sulphuretted hydrogen, carbonic oxide, and perhaps nitrous gas, when breathed occasion death immediately; but at the same time they produce certain changes in the blood, and therefore kill, not merely by depriving the animal of air, but by their specific properties*.

Other gases again, hydrogen namely, and nitrogen, occasion death when breathed, simply by depriving the animal of atmospheric air.

The preceding sorts of gases have been deemed respirable, inasmuch as they admit of being drawn into the lungs. One other kind still remains, which is termed irrespirable. Carbonic acid, and possibly acid and alkaline gases in general, are of this description. The instant that a draught of carbonic acid comes in contact with the aperture of the glottis, the latter is spasmodically closed, so that the attempt to inspire is ineffectual. The same thing happens when an animal is drowned in water or in quicksilver; and in each case the lungs are found emptied to an extraordinary degree, by the expirations which the animal makes before each renewed and fruitless effort to inspire.

The air thrown out of the chest in ordinary breathing contains an aqueous vapour, or carries off by evaporation the liquid which lubricates the inner surface of the air-cells and bronchi, of the trachea, the larynx, and the fauces. According to Dr. Hales, the quantity of fluid from this source amounts to about twenty ounces in the twenty-four hours: according to

* Thomson's Chemistry, vol. iv, p. 602.

Dr. Menzies, to six ounces: according to Mr. Abernethy, to nine ounces: according to Dr. Thomson, to nineteen ounces. M. Magendie has ascertained that a large proportion of this vapour is derived from the membrane lining the mouth and fauces, and mentions that its quality is readily modified by changes in the state of the blood. If odorous substances be placed in a serous cavity or injected into a vein, the breath acquires their odour. If a solution of phosphorus in oil be thrown into the veins of a dog, its expirations are luminous in the dark, and in the light appear loaded with a thick white vapour, which consists of phosphoric acid*.

The fine membranous texture of the lungs, which appears to allow an instantaneous passage to the gaseous fluids that are absorbed by or separated from the blood, is readily permeated by the substances which the air holds in solution. Thus the vapour of turpentine, when inhaled, finds its way into the blood, the urine acquiring in a short time that smell of violets, which characterizes the absorption of turpentine. By the same channel the fumes of tobacco find entrance into the system; and probably likewise those miasmata, which are of so delicate a nature, that their existence is detected only by the influence which they exert upon the human frame.

Respiration has a remarkable consent with the action of the heart. When the pulse is frequent, the breathing is hurried; when the pulse is slow and gentle, respiration is scarcely to be observed: when, for experiment's sake, we breathe more frequently than usual, the pulse becomes more frequent; when the breathing falls back to its usual rate, the heart's action again gradually subsides. The means by which this consent is established are unknown.

Respiration is remarkably modified by different affections of the mind. In some states of highly-wrought emotion the breathing is hurried and difficult; at the same time the voice is observed to fail. Perhaps both phenomena result from the spasmodic action of the muscles which close the glottis. After violent bodily exertion breathing is more frequent and the inspirations are deeper.

Each act of inspiration requires a special impression through the nerves upon the muscles which dilate the chest. When

* Magendie, Elémens de Phys. tome ii, p. 348.

the spinal cord is divided without violence above the origin of the phrenic nerves, respiration ceases at once, while the heart's action continues without undergoing any immediate change. When the phrenic nerve is irritated in an animal immediately after death, the diaphragm acts. When the phrenic nerves are divided in a living animal, the diaphragm is in a great measure paralyzed; but respiration continues through the alternate action of the muscles which raise and depress the ribs. Respiration is always performed with a conscious effort during our waking hours; but we seem not to regulate the frequency of its recurrence or its limits: nevertheless, we can at will enlarge or diminish the area of the chest, and stop, accelerate, or retard the act of respiration. When we attend to our breathing, or regulate its rate, it quickly becomes fatiguing; but the same happens with any voluntary and habitual action, if we attempt to perform it analytically by directing the attention to every step in its progress.

The influence of the pneumogastric nerves on breathing is imperfectly understood. In general, when these nerves are divided about the middle of the neck, respiration immediately becomes laboured, or hurried and irregular, and the animal dies in a few hours. This speedy death probably ensues in consequence of the muscles, which tend to open the passage of the glottis, being paralyzed by the experiment, while the opposite class remains unaffected by the division of the nerves. In an ass in which laboured breathing was produced by cutting through the par vagum, I found the respiration to become easy and natural upon opening the trachea; it continued so for three hours, when the animal was destroyed. In a dog in which the par vagum was divided in the neck, the animal survived three days: there was dyspnœa with frequent vomiting, and the stomach was found to have become inflamed. According to the observations of Sir B. Brodie, after the division of the par vagum a less quantity of carbonic acid is evolved, the respirations are much diminished in frequency, and the blood in the arteries assumes a darker hue; but its natural colour may be restored by artificially inflating the lungs*. Dr. W. Philip mentions that the dyspnœa produced in dogs and rabbits by the division of the par vagum in the neck, may be relieved by

* Phil. Trans. vol. cii, p. 390.

the continued application of galvanism to the chest: the animals nevertheless die: but the surface of the lungs, though reddened generally, appeared to Dr. Philip in this experiment not to show the patches of red, nor the bronchial cells the quantity of frothy mucus, usually observed after the division of the pneumogastric nerves.

SECTION III.

Of the Circulation through the Body.

All the phenomena of the circulation, which we have hitherto considered, may be viewed as preparatory to one important object,—the transmission of arterial blood through the capillary vessels of the aortic system, in which it conduces immediately to the support of life. It is here that the blood becomes deteriorated; when having lost its florid hue and become venous, it has to toil back to the heart and through the lungs to re-acquire its vivifying properties.

The phenomena dependent upon the circulation through the body, may be classed under the heads of excitement, secretion, the distribution of heat, and absorption.

I. The functions of the nervous and muscular systems appear to flag if arterial blood be not propelled in adequate quantity and with sufficient force through their capillary vessels; and although the term excitement may be an improper term to denote the influence which the blood in this instance exerts, and which may be but a part of nutrition, yet the phenomena are so remarkable as well to merit separate consideration. Perhaps they are of the same nature with the following circumstance observed by Dr. Edwards. When frogs are deprived of their hearts, they continue for a time to exhibit voluntary motion; if they are plunged in water, however, they quickly lose all appearance of life, and remain motionless and insensible under mechanical lesion; but upon withdrawing them from the water as soon as they have fallen into this state, they revive and move spontaneously. The exciting or invigorating influence of the atmosphere in this case may serve to

illustrate the action of arterial blood upon the organs of warm-blooded animals *.

1. When from hemorrhage, or from feebleness of the heart's action, arterial blood is thrown with less force and in less volume than usual upon the brain, fainting is ushered in by sensations of languor and feebleness, the ears ring, giddiness ensues, consciousness is lost. If in such a case the nervous system be excited by ammonia held to the nostrils, the heart beats more vigorously; and if the patient be laid in a horizontal posture, the flow of arterial blood to the brain is facilitated: by these means the conditions which produce syncope are removed, and the fainting person revives. It deserves to be remarked, that continued faintness after hemorrhage is to be encouraged as a salutary provision in cases where we cannot directly command the flow of blood; while faintness lasts, the tendency of the blood to coagulate is considerably increased, upon the effects of which the prevention of a return of hemorrhage greatly depends. By repeated or profuse hemorrhage, an exsanguinated condition of the body is produced, with alarming debility, which perhaps authorize, as Dr. Blundell a few years since argued, the transfusion of blood in such cases from the veins of a healthy person. The original experiment of Lower, performed about the year 1660, consisted in connecting by means of a tube an artery of one animal with the vein of another; in one instance a healthy man thus received into his system about nine ounces of the blood of a young sheep without suffering from it: but subsequently the operation being employed medicinally met with some notable failures and fell into disrepute. Dr. Blundell has made it appear that the transfusion of blood in animals of different species may be fatal; but has shown that in animals of the same species, if the operation be performed with sufficient adroitness and celerity, the blood may be successfully and safely transferred by means of a syringe †.

2. When any cause prevents the introduction of atmospheric air or of air containing oxygen into the lungs, the blood is returned unchanged to the left side of the heart, venous instead of arterial blood is thrown into the brain, and

* De l'Influence, &c., p. 7.

† Medico-Chirurgical Trans. vol ix, p. 50; and vol. x, p. 269.

consciousness is suspended. This state is termed asphyxia; the feelings with which it commences were ascertained by Pilâtre de Rosier, who placed himself in irrespirable air by entering into a brewer's tub while full of carbonic acid evolved by fermentation. A gentle heat manifested itself in all parts of his body, and occasioned a sensible perspiration. A slight itching sensation constrained him frequently to shut his eyes. When he attempted to breathe, a violent feeling of suffocation prevented him. He sought for the steps to get out, but not finding them readily, the necessity of breathing increased, he became giddy, and felt a tingling sensation in his ears. As soon as his mouth reached the air, he breathed freely, but for some time he could not distinguish objects; his face was purple, his limbs were weak, and he understood with difficulty what was said to him. But these symptoms soon left him. He repeated the experiment often, and always found that as long as he continued without breathing, he could speak and move about without inconvenience; but whenever he attempted to breathe, the sensation of suffocation came on *.

Symptoms very similar appear to have been produced in one experiment of Messrs. Allen and Pepys, when the same three hundred cubic inches of atmospheric air were passed and repassed from eight to ten times through the lungs: the operator became insensible. It deserves remark, that the air which had been employed was found to have gained only ten per cent. of carbonic acid; so that life, it appears, would probably be lost before the entire consumption of the air of a confined space. Lavoisier found, however, that by repeatedly withdrawing an animal and reviving it, it might be made to consume nearly all the oxygen of a given quantity of atmospheric air before death. Otherwise birds die before two-thirds, and mice and Guinea pigs before three-fourths of the oxygen of the air are destroyed.

When the influence of causes which produce asphyxia is prolonged, the face becomes bloated and livid, the efforts at respiration cease, and the heart's action gradually fails. The first attempt to be instantaneously made in such a case is to inflate the lungs, either with fresh atmospheric air blown with bellows into the nostril, or with air thrown from the lungs of an

* Journal de Phys. xxviii, p. 418.

assistant into those of the asphyxiated person. The body as a general rule should be kept warm; but in cases from the burning of charcoal, the application of cold is said to be useful.

The period is not determined at which the power of resuscitation is lost after breathing has been wholly prevented: it probably does not much exceed four or five minutes: about this time life may be considered irrecoverably gone, not merely in consequence of the continued suspension of the energy of the brain, but because the heart appears to lose its irritability when florid blood is not circulating in its vessels. The experiments of Sir B. Brodie and of Dr. Wilson Philip, which have been already mentioned, show that after the removal of the brain and spinal cord the heart will continue to act for a length of time, if by means of an artificial respiration it continues to receive florid blood; but if this excitement be withheld, the tendency of the heart to alternate action and relaxation quickly ceases.

3. When nitrous oxide is breathed, although it is uncertain in what degree and by what means the nature of the blood is modified, yet its effects upon the brain are remarkable, and illustrate in a different manner the stimulating effect of the blood. In this instance its power of excitation is increased; and phenomena occur resembling considerably those of intoxication; a degree of vertigo is experienced; the spirits are exhilarated; the muscular force appears increased, and a tendency to violent bodily exertion ensues. When a mixture of oxygen with hydrogen is breathed, a sedative effect appears to be produced. On breathing oxygen nearly pure for a short time, a general glow over the body, with gentle perspiration and quickened pulse, has been observed to take place.

4. When warm water is injected into the veins of an animal after an equal quantity of blood has been drawn from its body, the animal becomes enfeebled, and its nervous energy diminished. Magendie found the excited state of a rabid dog temporarily subdued by this means.

5. If air be thrown into the jugular vein of an animal suddenly and in large quantity, a peculiar sound is heard in the chest; the animal utters cries expressive of suffering and quickly perishes. If air, however, be introduced gradually into the veins, it frequently happens that no symptom follows.

The fatal effects of air becoming mixed with the blood suggests a caution in reference to operations in the neck, by which the external jugular vein may be opened. It has happened in such a case that air has been drawn during inspiration through the open vein into the right cavity of the heart; faintness, cold perspiration, with a peculiar noise in the chest, ensued, and the patient expired in a quarter of an hour *.

Medicinal substances introduced into the blood in small quantities act promptly and violently; they are thus administered in the veterinary college at Copenhagen. Oily and viscid substances introduced into the blood produce death rapidly, by obstructing the pulmonary capillaries. An American physician, it appears, tried in his own person the injection of a small quantity of castor oil into the blood. Nausea, with a taste of oil in the fauces, an indescribable sensation ascending towards the head, faintness, with spasm of the muscles of the jaws and an imperfect articulation, griping with tenesmus, ensued, and the imprudent experimentalist did not regain his health for several weeks †.

II. From the blood in the capillary vessels of the aorta the various substances of which the body consists, or which are thrown out upon its surfaces, appear to be separated or secreted ‡. It is not known whether apertures exist in the capillaries specially organized for this purpose, or whether the different elements transude through an uniformly porous texture. When size and vermilion have been thrown into the aorta so as to inject the whole body, there is found in the

* Magendie, Journal de Physiologie, tome i, p. 193.

† Magendie, Elémens de Physiologie, tome ii, p. 431.

‡ There are probably two exceptions to this statement. The bile appears to be secreted from the capillaries of the vena portæ; and the aqueous vapour of the lungs is perhaps in part supplied from the capillaries of the pulmonary artery. The reader will likewise observe, that in describing secretion and venous absoption in connection with the *circulation of the body*, I am using an arrangement purely arbitrary, and which I adopt only because the instances of *pulmonary* secretion and absorption are confined to one or two cases. The capillaries of the pulmonary artery imbibe substances that enter the lungs with the air we breathe, as for example the vapour of turpentine; and in the opinion of many physiologists the same vessels continually secrete carbonic acid. The pulmonary capillaries seem naturally as well fitted for both the functions adverted to, as the aortic capillaries.

serous cavities a quantity of colourless size, which must have been strained through very minute orifices, and is supposed to illustrate the mechanism of secretion. But in truth we know very little respecting the intimate nature of this phenomenon. Nor does it much aid our inquiries to classify its products according to their chemical relations: but it is interesting to remark, that although the elements of one secreted substance are readily distinguishable in the blood, while those of another have properties totally unlike that fluid, yet that the quantity of secretion always has reference to the quantity of blood circulating in a part: that when the former is increased, as from the mamma after parturition, the arteries of the part are enlarged: and conversely, that in order to check the increase of a vascular tumour, it has occasionally been found sufficient to tie the main artery leading to it.

Secretion furnishes products that are of two kinds; those, namely, which belong to the constitution of organs, being either solid or fluid; and such as are poured out in variable quantities upon the skin or on mucous surfaces, from which they are mostly mechanically removed before their function is attained. The former are called instances of nutritive, the latter of functional secretion.

1. No special organization appears necessary for nutritive secretion, or for the separation from the blood of the elements by which the body grows. Capillary vessels that carry red blood are distributed with considerable minuteness in every organ; and it may be presumed that growth takes place by the separation of the requisite elements from the blood in these vessels, through some modification of the principle of *exosmose.* Plants share the function of nutritive secretion with animals; and accordingly it seems in great measure independent of the influences peculiar to animal life. The hair and nails are said to grow after death: in a paralyzed limb, growth and the common phenomena of reproduction take place. When the fifth pair of nerves had been divided upon the petrous portion of the temporal line in a rabbit, upon breaking off the crown of an incisor tooth, I found the part reproduced as rapidly as in an animal in which the nerves were entire. The human mola is sometimes found to have attained considerable development without either brain or spinal cord. Dr. Clarke met with a case, in which after the birth of a perfect fœtus, another sub-

stance was expelled, inclosed in a distinct bag of membranes. The membranes consisted of deciduæ, chorion, and amnios, and had a placenta belonging to them, which was attached to the placenta of the perfect child. The mola itself was about four inches in length and three in breadth, of an oval figure, and attached to the placenta by a small and thin funis. There was no vestige of head or neck, no ribs, nor clavicle, nor scapula: it had four projecting parts, of which one bore an imperfect resemblance to the foot of a child. The surface was covered with the common integuments: the soft parts consisted of an homogeneous fleshy texture, but without any regular or distinct arrangement of muscular fibres, and was very vascular throughout: it contained an os innominatum and an os femoris of the natural size at birth, with a tibia and fibula shorter than natural. A portion of small intestine with a peritoneal covering and mesentery was found, but no glandular substance. It had neither heart nor lungs; neither brain, spinal marrow, nor nerves. The umbilical cord consisted of an artery and vein. Before the internal structure was examined, the navel-string of the perfect fœtus was injected; from whence the injection passed through both placentæ, and then into the substance of the mola*.

Nevertheless it has been proved, in the instance of one organ of very delicate fabric, that its nutrition is disturbed upon the division of one of the nerves which supply it. M. Magendie found, that when the fifth nerve is divided in the cranial cavity of a rabbit close upon its apparent origin, the surface of the eye inflames at its upper part, and the upper segment of the cornea becomes clouded. And what is still more remarkable, as tending to show conjointly with the preceding experiment that the influence of nerves upon nutrition is in part independent of the brain, M. Magendie found that if the fifth nerve be destroyed upon the petrous portion of the temporal bone, where its destruction involves that of the ganglion of Gasser, the entire cornea becomes opaque in twenty-four hours, and the opacity daily increases: on the second day the tunica conjunctiva reddens and secretes pus, and the iris becomes inflamed and covered with lymph; about the eighth day the cornea begins to ulcerate in its centre and at its edges, the eye

* Phil. Trans. vol. lxxxiii, p. 154.

bursts, and the humours being discharged, wastes and shrinks to a small nodule *.

The inflammation of the stomach, which ensues upon the division of the par vagum in animals that survive the operation for three or four days, is probably a phenomenon of the same kind as the preceding.

Nutritive secretion has a strict reference to the physical impressions made upon a part. When any part of the frame happens to be habitually used in an employment requiring the exertion of mechanical strength, the muscles of that part become larger, firmer, and more powerful, the bones enlarge, the sinews become stronger. If continued pressure is made upon a bone, such for instance as is sometimes made upon the lower jaw through the use of instruments in weakness of the spine, an exostosis is liable to rise from the bone, over which the skin is not tensely extended, but *grows* so as to form a loose capsule containing it. If the pressure be now discontinued, the tumour wastes and disappears. Thus again if a limb is kept absolutely at rest, its different textures are found to waste, becoming diminished in bulk and in strength. Medicines seldom appear directly to affect nutritive secretion; yet mercury in some instances appears to act locally in reducing the thickening of parts that has followed inflammation; liquor potassæ taken internally sometimes answers the same purpose; and iodine has been thought to exert a specific influence in reducing the enlarged thyreoïd gland.

2. The saliva, the bile, the urine, the perspiration, are instances of functional secretion. They are liquids, which exude upon mucous surfaces, or upon the skin; they are formed, as occasion requires, in variable quantities, and they are speedily removed from the surfaces on which they are produced for some purposes in the vital œconomy. Some of these fluids, as for instance the perspiration and the urine, are probably wholly excrementitious: others, as the saliva, are perhaps wholly reabsorbed; a third set, including the bile, seems to partake of both these characters.

The kind of organ in which functional secretion takes place is greatly diversified. In one instance, as in the conjunctiva, an

* Magendie, Journal de Physiologie, tome iv, p. 302, et 176.

uniform vascular superficies appears to pour out the fluid. In another, as in the stomach of the ostrich, numerous orifices are seen upon a surface, each of which leads into a sac of membrane lying in intricate folds, so as greatly to increase the vascular superficies. The lacunæ of the urethra, which are plain shallow pouches of mucous membrane, are among the simplest secreting organs of this description. In a third instance, as in the pancreas, a fleshy substance presents itself, consisting of numerous similar and coherent particles, which is termed a conglomerate gland. From each separate molecule of the gland, one excretory tube at least issues, the mode of communication between which and the arteries and veins of the part is supposed to be transudation through the coats of the capillary vessels and of the capillary excretory tubes, that lie in immediate juxta-position. In general the excretory tubes of a conglomerate gland coalesce to form a single trunk. Each elementary portion of such a gland resolves itself into blood-vessels and excretory tubes with nerves and lymphatics. It is the commonly received opinion, that a vascular membrane is all which is requisite for secretion, and that the other contrivances, which have been described, are but methods of conveniently packing a large extent of secreting surface in a small compass.

Functional secretion is to a remarkable degree influenced through the nerves. Upon one affection of the mind the tears flow, upon a second the urine, upon another the saliva: yet I found upon cutting the nerves of the kidney in a dog, that in half an hour afterwards a quantity of urine had accumulated in the pelvis of the kidney, and in the ureter, which had been tied. In this as in the first kind of secretion, physical impressions made upon the secreting organ directly influence the rate of production. Upon the removal of the young from its mother the secretion of milk after a short time entirely ceases, in circumstances where the gland would, if the demand for milk had continued, have continued its action for several months. The influence of medicines tells immediately upon functional secretion. Many classes of drugs derive their names from the power which they possess of increasing the flow of saliva, of the urine, and the like; and their value in therapeutics, from the connection which exists between the rate of any one secretion and the condition of the whole body. Sir

B. Brodie ascertained that the secretion of urine does not take place in animals, in which after decapitation the circulation of the blood is sustained by an artificial respiration *.

Three suppositions present themselves, as to the place in which the secretions are formed : either they may be produced in the blood while circulating in the system at large, and be simply separated through the intervention of secreting organs,—or the entire process of secretion may take place in the capillaries in each part,—or the elements of the different secretions may spontaneously develop themselves to a certain extent in the blood at large, yet require the influence of the capillary tubes in the part where they are separated, for their complete elaboration. The principal fact with which we are acquainted upon this subject is the observation of MM. Prévost and Dumas, that after both kidneys have been removed, an animal survives several days, during which the characteristic element of the urine accumulates in considerable quantity in the blood.

III. When the resemblance was ascertained between the effects of combustion and of respiration upon atmospheric air, the lungs, which were previously supposed to act in cooling the heart, were invested by physiologists with the office of producing animal heat. The difficulty of accounting on this supposition for the equal diffusion of warmth throughout the body was evaded by, and served to confirm the beautiful theory of Crawford. By careful experiments Crawford became satisfied that arterial blood has a greater capacity for heat than venous blood, in the ratio of 114.5 to 100. The heat therefore liberated in the lungs during the conversion of oxygen into carbonic acid might instantly again become latent, forming an unobserved element of arterial blood in its flow through the body; till at the subsequent conversion of arterial into venous blood in the capillaries, it would become liberated at each point in the system. Numerous observations, which have successfully established that the vital heat in different animals, in the same individual, and even in plants, has a close relation to the quanty of oxygen consumed by them, seemed to place the theory of Crawford beyond the reach of innovation. Recent inquiry concurs with former experience upon the point before us. Dr. Edwards has ascertained, that young animals con-

* Phil. Trans. vol. ci, p. 48.

sume in proportion less oxygen than adults, and have a less power of generating heat; and that young animals differ among each other in the power of producing heat, something in the ratio of the oxygen which they destroy. Where respiration is imperfect, as in asthmatic patients, the temperature of the body is lower. Where pure arterial blood does not circulate through the body, as in those in whom a communication exists between the right and left cavities of the heart, the temperature is below the usual standard.

But the experiments of Sir B. Brodie show the preceding argument to be fallacious, and prove that Crawford must have overrated the difference in the capacities for heat of arterial and venous blood, upon which his theory rested. Two rabbits, as nearly alike as possible, were destroyed by decapitation after securing the vessels in the neck: in one the circulation was kept up by means of artificial breathing; the other was left untouched in the same room at the same temperature. Of these two dead rabbits the first was observed to cool more rapidly than the second: yet in the first the chemical influence of respiration was perfectly maintained, the blood circulating through the lungs from a dark hue assumed the arterial character, that circulating through the body became venous; and the air respired was deteriorated exactly as by the breathing of a living rabbit. Nevertheless, heat was not derived in sufficient quantity from this source to make up for the lowering of temperature produced by the fresh draughts of cool air into the lungs of the dead animal: the thermometer at the expiration of thirty minutes stood at 97° in the rectum of the first, at 98° in the rectum of the second rabbit*. Subsequent researches upon this subject by Dr. W. Philip and Dr. Hastings tend to show, that the rapid cooling of the first animal in the experiment detailed may have resulted in part from too large an inflation of the chest; that upon avoiding this excess, the process of cooling appears even to be retarded by artificial respiration, but not to a degree that invalidates Sir B. Brodie's experiments.

But although the theory of Crawford be thus set aside, it remains possible that arterial blood may prove by some other method the source of animal heat. A general ratio seems to

* Phil. Trans. vol. ci, p. 36, et seq.; and vol. cii, p. 380.

exist between the temperature of parts and the afflux of arterial blood; and the following experiment by Dr. Wilson Philip may serve to show how the decomposition of the latter through an agency, in many instances analogous to the nervous influence, may produce heat. Upon applying the galvanic influence to arterial blood immediately upon its being drawn, an evolution of heat amounting to 2° or 3° took place, while the blood assumed a venous hue. The trial was made with the arterial blood of a rabbit, the rise of temperature ceased to show itself in two minutes after the blood began to flow from the vessel, but the change in colour continued to be produced, accompanied with an extrication of gas through the galvanic influence. No rise of temperature could be produced in venous blood by the same means *.

Physiologists at present incline to the belief that the production of animal heat depends upon the nervous influence: yet the best evidence which we possess shows only that temperature may be modified through the nerves, like every other physical endowment of the body. Sir Everard Home found, that upon the division of the nerves distributed to the growing antler, its temperature fell immediately several degrees, but rose again a few days afterwards even higher than the temperature of the opposite horn †. Sir Everard mentions on the same occasion some curious instances of a partial extrication of heat, which he refers to nervous agency: the oviduct of a frog ready to spawn is two degrees hotter than the heart; and it appears on the assertion of Dr. Granville, that during labour the heat of the uterus is sometimes raised to 120°; but a very similar phenomenon has been observed to occur in plants, in which no organs analogous to a nervous system have been traced: M. Huber observed, that when the temperature of the atmosphere stood at 21° cent. a thermometer surrounded with spadices of the arum cordifolium during the process of fecundation stood at 42° ‡.

Upon the whole, we must admit that the source of vital heat remains unknown. Its remarkable influence in the human œconomy will be subsequently considered.

IV. The facts which we possess respecting imbibition by

* Inquiry, &c., p. 242. † Phil. Trans. vol. cxv, p. 7.
‡ Ellis on Respiration, &c. p. 204.

means of the blood-vessels are principally owing to the researches of M. Magendie, from which I extract most of the following observations.

The thigh of a dog, which had previously been stupefied by opium, was separated from the body by the division of every part but the crural artery and vein; into each of these vessels a quill was introduced and tied with two ligatures, between which the vessel was divided: thus a channel was provided for the circulation of the blood, and all other communication between the body and the limb was cut off. Two grains of the upas tieuté were then inserted into a wound in the foot of the separated limb. The poison manifested its effects upon the system in the ordinary time, that is, in about four minutes; and we are given to understand that the animal died within the tenth minute.

A fold of small intestine (this experiment, though founded upon M. Magendie's, was made by M. Ségalas) was drawn out of a wound in the belly of a dog. All the blood-vessels passing to and from it were tied but one large artery. A vein punctured upon the mesentery allowing the escape of blood prevented congestion. The lacteal vessels and the nerves were left entire. The fold of intestine was then tied at both extremities, was opened, and an aqueous solution of the alcoholic extract of nux vomica poured into it. During the hour which followed, the poison produced no symptoms. The ligature being then removed from one of the veins, blood was allowed to return to the heart after circulating through the previously isolated portion of bowel. In six minutes from this time the poison took effect.

The preceding phenomena admit of two hypothetical explanations. We may suppose either that the veins possess a special power of absorption through some mechanism not as yet discovered; or that a poisonous substance may find its way into the blood through the coats of the vessels, by virtue of that imbibition or transudation of a nature partly chemical partly mechanical, which takes place in dead organized matter, and which it is analogically probable takes place in living matter as well. The latter supposition has the recommendation of assuming nothing. The following facts appear to me to support it.

If a piece of beef be put in salt, in a few days the saline fluid will penetrate the whole mass..

If the abdomen of an animal be opened some time after death, the parts adjoining the gall-bladder will be found to be deeply tinged with bile.

If the theca vertebralis of an animal is opened, during life or soon after death, a quantity of fluid is found in it: a like quantity of fluid is not found if the examination is delayed till some days have elapsed.

If half an ounce of acidulated water is introduced into the pericardium of a dog killed twelve hours before, and warm water is injected in a continued stream through the coronary arteries, so as to flow into the right auricle of the heart, in four or five minutes the water gives unequivocal evidence of containing acid.

In an animal that had been killed by the wound of a Javanese poisoned arrow, the parts around the wound became of a brownish yellow colour for the depth of several lines, and took the bitter flavour belonging to the poison.

The preceding instances establish the fact, that dead flesh will allow of free imbibition or transudation; so that a substance introduced into it, whether liquid or solid (so that it be capable of being dissolved by the juices of the flesh), will find way into the cavities of its blood-vessels.

If a drop of ink is placed upon the peritoneum of a living animal, it sinks into it and forms a large circular stain, which at first is confined in depth to the serous membrane, and takes a much longer time to penetrate the subjacent textures.

If a small quantity of ink is introduced into the pleura of a young dog (the experiment succeeds better upon smaller animals), in an hour the pleura, the pericardium, the intercostal muscles, and the surface of the heart itself, are sensibly discoloured, and assume a black hue.

If the jugular vein of a young dog is raised from its place without interrupting the circulation, a slip of card being introduced between it and the adjoining parts, and the vein is carefully denuded of the surrounding loose texture, and a thick aqueous solution of the alcoholic extract of nux vomica is placed upon the middle of the card so as to surround and bathe the vein, in less than four minutes the effects of the

poison show themselves; at first faintly, but soon after so actively as to require the employment of artificial respiration to keep the animal alive.

On comparing these results with the preceding series, it appears impossible to doubt that they depend upon a like transudation taking place in the living body to that which occurs in the dead. But various circumstances have been ascertained to prevent, or retard, or accelerate this mode of absorption; and it is remarkable that they are consistent with, if they do not materially strengthen, the hypothesis which we have adopted.

Imbibition takes place more readily upon serous than upon mucous membranes, more readily upon very vascular surfaces than upon those which are less so.

The method common among barbarous nations of extracting poison from wounds by suction, is consistent with the supposition that it makes its way into the system by mechanical imbibition.

If a ligature is applied around a limb bitten by a venomous serpent, no symptoms appear as long as the pressure is kept up. The ligature stops the circulation of the blood, and thus is calculated to prevent the poison being conveyed to the heart and to the brain, when it has penetrated by transudation the cavities of the vessels and has become mixed with the blood. If it be true that continued pressure of a ligature, though insufficient wholly to stop the circulation, yet destroys the effect of the poison, this result may be attributed to the gradual introduction of the poison into the system in quantities too small to produce any symptoms.

The interesting experiments of Dr. Barry upon the absorption of poisons are to be explained upon the same principle. Dr. Barry found that the usual effects of introducing prussic acid, strichnine, or the upas tieuté into the subcutaneous tissue of animals are prevented, if a cupping-glass is applied over the wound, or in its immediate vicinity. If the cupping-glass is applied for a short time only, and then removed, the symptoms of poisoning show themselves; but they disappear again upon the reapplication of the pressure. If the cupping-glass is applied for a considerable length of time, upon its removal the poison is found to have lost its effect; and in this manner

poisoning may be prevented, or arrested after the symptoms have begun to show themselves. The application of the cupping-glass has this among other important advantages over the ligature, that it not merely stops the flow of the blood from the part, but even draws the liquids in its vicinity within or towards its circumference, causing them, in fact, even to exude, if the cupping-glass is applied over the wound. If the cupping-glass is applied in the neighbourhood of the wound, an incision between the edge of the cupping-glass and the wound allows the poison to act by interrupting the natural derivation of the fluids towards the part from which the atmospheric pressure has been removed *.

If an animal is placed in a state of artificial plethora by injecting a large quantity of warm water into its veins, a poison introduced into the pleura, which ordinarily shows its effects in two minutes, in half an hour produces no symptoms. Upon drawing a large quantity of blood from a vein, the effects of the poison discover themselves.

If a quantity of blood is drawn from an animal, and is replaced with an equal quantity of water, poisoning takes place in the same time as under ordinary circumstances.

If a quantity of blood is drawn from an animal and no substitution of another fluid made, a poison which naturally operates in two minutes produces symptoms in thirty seconds.

In these cases it appears that the degree of distension of the vessels influences the facility with which a poison is introduced into the system: but the same result should take place on mechanical principles, if the mode by which the poison makes its way be mechanical transudation through the coats of the blood-vessels.

In therapeutics the principle is well established, that medicines act with increased and more rapid effect after venesection.

If a solution of prussiate of potass is injected into the pleura, and a solution of sulphate of iron is introduced into the abdomen of a living animal, in general five or six minutes are required for their communication through the diaphragm. But this communication M. Fodera found to be instantaneous

* Memoire sur l'Absorption, par David Barry, M.D.

when a current of the galvanic fluid was directed through the diaphragm, — a phenomenon remarkable from its agreement with the effects of the like influence upon the transmission of liquids through inert capillary tubes.

Such is the mass of evidence by which it appears to be well established, that a kind of transudation takes place in living as well as in dead textures, and is the principle through which foreign matter in contact with a vascular surface finds its way into the circulation. The investigation of the laws of this transudation, which belongs to the same class of phenomena with the *endosmose* and *exosmose* of Dutrochet, is one of the most important to the progress of physiology that the present period of the science is likely to see successfully accomplished. It is probable that the nature of secretion as well as of absorption will equally be elucidated by it.

CHAPTER V.

OF DIGESTION.

The matter lost by cutaneous and pulmonary transpiration, by the urine, and by other secretions, which are wholly or in part eliminated from the body, is a perpetual drain upon the blood. To supply this waste, a fluid is elaborated from the food, which in essential qualities nearly resembles the blood, which is absorbed and poured into the veins by a distinct set of vessels, and, mixing with the blood, in a short time ceases to be separately distinguishable in it. The process by which the nutritious element is extracted from the food is termed Digestion.

In the lowest animals digestion is a very simple process. The hydra viridis, which consists of a bell-shaped sac, seizes the insects on which it preys with its tentacula, and thrusts them into its cavity; the business of digestion immediately commences: great part of the insect that has been swallowed disappears, having been first dissolved and then absorbed: the refuse matter is afterwards expelled through the same orifice at which it was received.

In the ascending scale of organization from the lowest animals to the highest, the digestive organs gradually become more and more complex: the alimentary canal becomes laid out in a series of chambers, in which the food undergoes successive changes antecedently to its separation into nutritive and excrementitious matter; and the gradual assimilation of the food is wrought, not by the influence of these several chambers and their products alone, but in great part through the chemical agency of copious secretions, that are formed in glandular parts in the neighbourhood, and are afterwards conveyed into the different chambers of the digestive apparatus.

The regular employment of these important organs, so essen-

tial to the continuance of individual existence, has not been left by Providence to the risk of being neglected through caprice or accident: but strong desires have been implanted in us, by which we are instinctively and irresistibly led to their proper use. Our first inquiries may be directed to that part of the process of digestion, with which consciousness has to do; or to the nature of those parts which are thrown into action in order to gratify a sense, yet in which at the same time the assimilation of the food commences.

SECTION I.

Of Hunger and Thirst; of the Mastication of Food, and of Deglutition.

We are led to take food by the appetites of hunger and thirst. If hunger is not gratified, an uneasy sensation of gnawing or dragging occurs, which is referred to the epigastrium; if thirst is not slaked, the mouth and throat become dry and parched. It is usual to attribute hunger to an affection of the nerves of the stomach, and thirst to an impression upon the nerves of the fauces and pharynx. But it is far from certain that either of these suppositions is just. Nausea is habitually referred to the stomach, upon the same grounds with the sensation of hunger; yet, according to the experiments of Magendie, after the removal of the stomach in an animal, nausea and retching may be produced by the injection of tartar emetic into the veins; and Dr. Gairdner remarked, that in the case of a man who had cut through the œsophagus, several buckets-full of water were swallowed daily, and discharged through the wound, without quenching thirst. The thirst, in this instance, it was afterwards found, admitted of being allayed by the injection of spirits diluted with water into the stomach*. It is, therefore, not impossible that a person might be hungry without a stomach, and thirsty without a throat.

Hunger frequently remains for half an hour or an hour after a hearty meal. Sleep allays it; violent emotions of the mind

* Edinburgh Medical and Surgical Journal, vol. xvi, p. 355.

prevent it. Hunger recurs at stated periods through the influence of habit. If the gratification of the appetite is withheld, it temporarily ceases, and a degree of nausea takes its place, with languor and exhaustion; then hunger returns with painful sensations at the stomach, and as a violent craving, which gets the better of every feeling of aversion and abhorrence, and the vilest food is swallowed with avidity.

We may now proceed to examine the parts into which the food is first received.

The fauces form an organ in which the solid food is divided into fragments, and rubbed down with a fluid to the consistence of a pulp, that it may leave its entire flavour upon the neighbouring sentient surfaces, and be readily conveyed in equal portions along the gullet in the act of deglutition.

The vaulted roof of the fauces is formed by the hard palate, around which are set the teeth in their sockets: this part may be considered as fixed during mastication. The lower jaw represents the alveolar processes of the upper maxillary bones, with which it contains an equal number of teeth, and against which it is capable of being pressed in various directions, so that the edges and grinding surfaces of the different teeth may act upon the food. The tongue, contained within the hollow of the lower jaw, forms the floor of the fauces, and when the mouth is shut, presents a convex upper surface in contact with the vaulted part of the palate. Three glands on either side, the parotid, the submaxillary, and the sublingual, pour saliva into the mouth, the inner surface of which is lined with a mucous membrane that is continuous at the lips with the skin; and many smaller glandular bodies within the lips and the muscles of the cheek, termed glandulæ labiales and buccales, contribute perhaps to the same office.

The teeth are thirty-two small bones, of which the crown or base, or body, is covered with enamel, and appears above the gum: the neck of a tooth is that part to which the gum adheres; the root or fang of each tooth is firmly wedged into the substance of the jaw. A tooth is fixed by its fang and neck; the crown is employed in dividing the food, and in the articulation of some of the letters.

By means of a longitudinal section the cavity of a tooth may be shown; which is naturally open at the extremity of the fang, and ascends through the neck into the crown of the tooth,

representing very faithfully its outward form. The cavity is seen to be wrought in the duller-coloured substance, or bone, of the tooth; and the glistening enamel appears disposed in a thin layer, thickest upon the cutting edge or grinding surface of the crown, and vanishing upon the neck of the tooth.

If a tooth is steeped in diluted muriatic acid, it retains its form, but becomes flexible; the acid dissolves the earthy matter, and leaves the animal substance with which it was combined.

The following is the composition of the bone of teeth:—

Animal matter	28.0
Soda with muriate of soda	1.4
Carbonate of lime	5.3
Phosphate of lime	61.95
Fluate of lime	2.1
Phosphate of magnesia	1.25
	100.00

The following is the composition of enamel:—

Animal matter	2.0
Carbonate of lime	8.0
Phosphate of lime	85.3
Fluate of lime	3.2
Phosphate of magnesia	1.5
	100.0

If a section is made through a tooth and the alveolar process which contains it after a successful injection with size and vermilion, neither the enamel nor bony part of the tooth appear in any degree reddened; but a very vascular membrane is seen to enter at the aperture of the fang and to line the whole of the cavity of the tooth. Branches from the ganglionic portion of the fifth pair of nerves may be traced to the cavity of the fang, upon which the sensibility of a tooth depends.

In this manner the teeth cohere with neighbouring vascular parts. Their mode of life and growth will be afterwards described. At present we have only to consider their mechanical agency in comminuting the food.

The four front teeth in each jaw are termed incisors. The crown of each incisor has a cutting edge ending transversely, and is wedge-shaped: the fang is single. The two central incisors in the upper jaw are larger than the rest, so as to throw

the remaining teeth of the upper jaw rather without or behind those of the lower, till the smallness of the last grinder in the upper jaw causes them to terminate at the same vertical plane.

A cuspidatus, canine, or eye-tooth follows on each side next to the incisors: a canine tooth is pointed, and larger than an incisor: its fang is single but of great length, and frequently bent at the extremity.

The opposite sets of cuspidati and incisores form two curved blades, which meet like those of scissors bent upon the flat; the incisores and cuspidati of the upper jaw generally fall before those of the lower.

The two teeth, which immediately follow each cuspidatus, have two points upon the crown, one without the other, and the largest external; they are called bicuspides: they have one broad fang fluted at its sides.

The three remaining teeth on each side of each jaw are called molares or grinding teeth; their crowns have five points. The molares of the lower jaw have two fangs, one behind the other: the molares of the upper have three, two of which are external: they rise in a slanting direction. This disposition of the fangs of the upper molares is intended to avoid the maxillary antrum; but it occasionally happens that one fang, and that more generally one of those of the second molaris, extends into the antrum. In the museum of Albinus there is an instance of the crown of a molar tooth growing into the cavity of the antrum, the direction of the fangs being reversed. The first molaris is the largest; the posterior, or dens sapientiæ, is small: its fangs grow together, and are short. The grinding surfaces of the two sets of molar teeth are exactly opposed to each other.

The strictest relation exists between the form of the teeth and the habits of animals. Thus in the horse, which crops the herbage by bruising and snapping it across, the incisors have broad flat surfaces which meet like the blades of pincers: in the incisor teeth of the beaver, which gnaws through the hardest vegetable fibre, a sharp chisel-like edge is preserved by the disproportionate distribution of enamel upon the fore part: in the lion the incisors are pointed: in the elephant, front teeth grow from the upper jaw only, and are prolonged into tusks, by the aid of which, with its trunk, the animal tears up the plants that serve for its food. The cuspidati are remark-

ably large in carnivorous quadrupeds to enable them to hold and rend their prey; and the character of the head in this class is determined by the prominence of the zygoma to give room for the thick temporal muscle by which the jaws are closed, and by the shortness of the jaws themselves, which saves expenditure of power in closing them.

The molares are best developed in graminivorous animals; on this occasion a third substance termed the crusta petrosa, having less hardness than the bone, as the bone has less than the enamel, is wrought into their composition; and as each of these three substances is exposed upon the grinding surface, the latter derives a permanent inequality from their different degrees of hardness favourable to the comminution of the food. The form of the heads of graminivorous quadrupeds is characterized by the length of the jaws in which the massive grinding teeth are set; by the long and flat zygoma, and by the depth and breadth of the branches of the lower jaw, to which muscles are attached, that move it forward and laterally.

The lower jaw consists of the curved piece of bone in which the sixteen lower teeth are set, and of a process or branch on either side which rises nearly at a right angle to be articulated by means of its condyle with the glenoïd fossa of the temporal bone. Each branch is of such a length, that when the lower jaw is fully raised, the two rows of teeth are equally pressed against each other, the front teeth locking, the molar teeth simply meeting.

The elementary motions of the lower jaw consist in its simple elevation or depression, in its horizontal movement forwards or backwards and from side to side.

1. During the depression or elevation of the lower jaw, the centre of motion falls about the middle of its branches. Or the lower jaw in rising or falling performs part of a vertical revolution upon an imaginary axis extending from side to side through the middle of its branches. In the depression of the jaw the angle is carried upwards and backwards, the condyle forwards and downwards sliding upon the interarticular cartilage which is interposed between it and the os temporis. The temporal muscles directly raise the lower jaw: the digastricus and other muscles which depress it, at the same time retract it, and thus admit of being brought into play even during the elevation of

the jaw, in order to modify the action of the masseter and internal pterygoïd muscles which tend to carry the jaw forwards as well as upwards.

2. The lower jaw may be carried forwards in a plane parallel to that of the alveoli of the upper jaw, by the action of the external pterygoïd muscles,—aided by the masseters and internal pterygoïd muscles, if the tendency of the latter to raise the jaw be prevented by the digastrici and various other muscles attached to the os hyoïdes. The muscles last alluded to are calculated simply to retract the jaw, when their tendency to depress it is neutralized by the temporal, masseter, and internal pterygoïd muscles.

3. The lower jaw may rotate horizontally round an imaginary centre, which falls in the middle of a right line joining the two condyles: the masseter of the same side and the pterygoïdei of the opposite concur in giving the jaw this movement, assisted by the digastrici and various other muscles attached to the os hyoïdes, the action of which preserves the movement horizontal.

By differently combining these simple motions, all the variety of pressure which the teeth make upon the food is produced.

The os hyoïdes is composed of three slight pieces of bone, a base and two cornua, forming a small horse-shoe figure, within and behind the more capacious curve of the lower jaw: upon this bone the mass of flesh which forms the tongue is supported. The central and largest muscle of the tongue is termed the genio-hyo-glossus: it extends from the symphysis of the jaw to the os hyoïdes in one direction, and to the tip of the tongue in the other. Other muscles descend obliquely, from the lower jaw to the os hyoïdes, which with the preceding raise the os hyoïdes, and carry the tongue forward or laterally. The linguales shorten the tongue, the stylo-glossi give it breadth and concavity, the hyo-glossi render it convex:—so ample is the provision for moving this organ to different parts of the fauces, whether to bruise the softer parts of the aliment against the palate, to mix it with the saliva, to place it under the pressure of the teeth, to assist in bringing out the taste and other sensible qualities of bodies in contact with the finely organized papillæ on its mucous surface, to urge the masticated food towards the pharynx, or to give articulation to vocal sounds.

The saliva is a transparent fluid like water, but much more viscid: it has neither smell nor taste: its specific gravity according to Dr. Thompson is 1.0038. Its constituents according to Berzelius are as follows:—

Water	992.9
Peculiar animal matter	2.9
Mucus	1.4
Alkaline muriates	1.7
Lactate of soda and animal matter	0.9
Pure soda	0.2
	1000.0

The glands that secrete saliva are three in number on each side: they are of an ochrey colour, and are composed of numerous molecules of different sizes, connected together by a very firm cellular texture.

The parotid gland is the largest of the three: it occupies the hollow between the mastoïd process of the temporal bone and the branch of the lower jaw; its duct, which is commonly termed the Stenonian duct, passes over the masseter muscle to reach and perforate the buccinator, and open upon the membrane of the fauces opposite to the middle molaris of the upper jaw. A small gland termed the socia-parotidis adheres to the Stenonian duct in its passage over the masseter. The portio dura traverses the substance of the parotid gland, which derives nerves from this source, from the superficial temporal branch of the third division of the fifth, and from the second cervical nerve.

The submaxillary gland is of an oval form: it is placed above the digastricus and between the lower jaw and the mylohyoïdeus muscle: its duct, termed the duct of Wharton, opens upon the mucous surface of the fauces at the side of the frænum linguæ. The nerves of this gland are derived from the gustatory and the maxillary ganglion.

The sublingual gland is frequently continuous with the posterior portion of the submaxillary gland, is oblong, and is placed between the mylohyoïdeus and the membrane of the mouth: its principal ducts or duct open into the duct of Wharton; several smaller ducts open from it into the furrow by the side of the tongue; its nerves are derived from the gustatory.

In the case described by Dr. Gairdner, to which I have already referred, from six to eight ounces of saliva were poured into the fauces during a meal, which consisted of broth injected through the divided œsophagus into the stomach: the quantity of saliva is probably greater which is produced under the stimulus of ordinary mastication. With this fluid the food is mixed while undergoing comminution in the fauces. The food acquires at the same time the temperature of the blood.

It does not appear that any notable effect is produced upon the aliment through the conjoined influence of the saliva and an elevated temperature. M. Krimer held in his mouth a piece of ham of a drachm weight for three hours. At the expiration of this time the morsel had become white upon its surface, and had gained twelve grains in weight *. Perhaps the qualities of the saliva are simply calculated to produce a ready mixture of the various kinds of food triturated with it.

The nature of sensations of taste will be afterwards described. The gratification of the sense of taste seems but to whet the appetite of hunger; to allay which deglutition instinctively follows. The morsel is thrown by the tongue to the back part of the fauces, and we swallow it as soon as its sapid juices have been diffused through the mouth, and its altered consistence shows it to have attained a state fit for deglutition:—a capacious sac termed the pharynx receives it.

The pharynx communicates at the fore part with the cavities of the nostrils, with the fauces, with the larynx: it is lined by a prolongation of the mucous surface common to these three parts: it is suspended to the basilar process of the occipital bone, and attached laterally to the pterygoïd processes of the sphenoïd and to the cornua of the os hyoïdes; thence it becomes narrower to the first ring of the trachea, where the alimentary canal assumes a cylindrical form, and receives the name of œsophagus.

The muscles which raise the os hyoïdes raise the pharynx with it: at the commencement of deglutition all the parts of the throat visibly ascend: the pharynx is drawn upwards to receive the morsel thrust towards it by the pressure of the tongue: and one muscle, the stylo-pharyngeus, which con-

* Versuch einer Physiologie des Blutes. Leipsic, 1820.

curs in producing this movement, seems specially intended in addition to expand the pharynx.

Three muscles throw their fibres round the pharynx, which are termed its upper, middle, and lower constrictors: their action is such as to compress any substance that has found entrance into the pharynx, and thus to expel it. But the pharynx is open towards several passages, and the contrivances are remarkable, and well deserve attention, which limit the progress of the food to one direction only, and force it to descend towards the œsophagus, instead of making its escape by the nostrils, the fauces, or the larynx.

What is termed the soft palate is a flap of flexible elastic substance about one-fourth of an inch in thickness and an inch in depth, which hangs as a loose curtain from the posterior edge of the palatine plate of the palate bones. The centre of its unattached margin is prolonged to form the uvula. Laterally two crescentic folds of mucous membrane are reflected from the soft palate to the sides of the tongue and pharynx: between these arches the tonsil, a mucous gland, is placed on either side. Each crescentic fold contains muscular fibres; the anterior contains the constrictor isthmi faucium; the posterior, the palato-pharyngeus: these muscles depress the soft palate, and narrow the aperture leading from the fauces into the pharynx.

By these means the communication with the fauces is so straitened, that the pressure of the tongue readily precludes the return of the food into the mouth when the constrictor superior pharyngis contracts.

But the principal office of the soft palate in deglutition consists in protecting the posterior openings of the nostrils: for this purpose it is necessary not merely that this flap of yielding flesh be carried before the food to the back of the pharynx; but that adequate tension be given to it to enable it sufficiently to resist the pressure of the constrictor superior pharyngis and of the tongue upon the morsel swallowed. Two muscles are provided in addition to those already described to give the tension required to the soft palate, namely, the levator palati mollis and the circumflexus palati: both descend obliquely forwards, the cartilaginous part of the Eustachian tube being interposed between them, from the extremity of the petrous portion of the os temporis: but while the former is

directly expanded into the substance of the soft palate, the latter is previously reflected round the hamular process of the sphenoïd bone, and re-ascends to its insertion : the two muscles thus become opposed in their action, and drawing in different ways upon the soft palate contribute to extend it over the pharynx behind the opening into the nostrils. Something of the effect of these parts in deglutition may be seen on pressing down the tongue with the handle of a spoon, and conveying the instrument towards the root of the tongue and the tonsils, when the peculiar sensibility of the back part of the fauces is excited, and an instinctive and irresistible action of deglutition ensues.

It sometimes happens that infants are born with a natural fissure of the soft palate in the median plane. When this is the case deglutition is commonly performed imperfectly, part of the aliment swallowed finding its way into the nostrils. However, many persons thus originally malformed gradually acquire a power of swallowing food without any part going wrong; but for this purpose it is requisite that they swallow each morsel leisurely. It is curious to observe the mechanism in action by which the imperfect palate is rendered capable of performing its functions justly: the means by which this is done may be seen on desiring the patient to perform the act of deglutition with the fauces empty, and the lips sufficiently apart to disclose the soft palate. At the moment of swallowing, the two parts of the velum pendulum palati are seen to be drawn downwards and inwards by the action of the circumflex muscles, so as nearly to meet. This circumstance is favourable to the success of the operation of staphyloraphe, as it tends to diminish the strain upon the sutures during deglutition.

The mode in which the respiratory tube is protected during deglutition can only be well understood in connection with the anatomy of the larynx. The epiglottis, a thin portion of elastic cartilage, rises vertically at the root of the tongue, and is broad enough when carried backwards to cover the aperture of the glottis: and there is no doubt that in ordinary deglutition this cartilage is pressed down by the food towards the orifice of the larynx. But the epiglottis was removed from animals in experiments by M. Magendie, and it has been lost by disease in human beings, without any essential prejudice to deglutition. The security of the larynx depends upon the contraction of the

muscles which close its aperture, namely, the arytænoïdeus transversus and the arytænoïdei obliqui. While these preserve their power of motion, the loss of the epiglottis is not felt: but if they be paralyzed, as through the division of the nervi laryngei interni, a part of the food finds its way into the larynx and violent coughing is produced each time that deglutition is attempted, even though the epiglottis have been left entire. I had a patient under my care in the Middlesex Hospital, who in the attempt to destroy himself, had made a deep horizontal wound into the throat between the os hyoïdes and thyreoïd cartilage. The incision was close upon the latter, so that the epiglottis was shorn off, and you might look into the pharynx, directly upon the front of the arytænoïd cartilages. Each time that this patient swallowed liquid, a small quantity escaped by the wound, but none appeared to enter the larynx; nor was coughing produced, nor any other symptom of laryngeal irritation. [see the subsequent account of the larynx.]

Deglutition consists of three stages; of the passage of the food, from the mouth into the pharynx, from the pharynx into the œsophagus, from the œsophagus into the stomach.

The action of pharyngeal deglutition may at any time be performed through a deliberate exertion of the will: at times it seems to take place, if not independently of volition, at all events uncontrollably. If the action of deglutition be voluntarily performed several times in succession, and nothing but saliva swallowed, the parts become fatigued, and the operation cannot be immediately repeated. The action of the lower part of the pharynx and of the fibres of the œsophagus is not consciously voluntary.

SECTION II.

Of the Nature of the Alimentary Canal from the Œsophagus downwards, and of the Fleshy Viscera connected with it.

That part of digestion, which the will directly controls, is limited to the fauces and pharynx: below the latter muscular action ceases to be voluntary, and common sensation is speedily lost. The elaboration of the food now proceeds rapidly; it

loses its original qualities, and assumes different characters, as it is successively submitted without our consciousness to the action of several viscera. It will help to simplify our present inquiries, if I prefix a general account of the nature of these viscera to the description of the different steps of the assimilative process which are conducted in them.

The alimentary canal below the pharynx constitutes a membranous tube of from five to six times the length of the body, the several parts of which are, the œsophagus, the stomach, the small and the great intestines.

When we consider this lengthened tube (for the purpose of yet further simplification) as a single organ, disregarding the differences of shape and structure which characterize its several parts, we remark that notwithstanding its thin and membranous structure, it throughout admits of being separated into three distinct layers or tunics.

The innermost, or mucous coat, so called from the nature of the secretion which exsudes upon it, is so delicate as not to allow of being separated from the next as a continuous membrane, till the part has been hardened by maceration in alcohol. The unadherent surface of the mucous coat is not plain, but resembles that of plush, being covered with a delicate pile, which where the individual shreds are larger and more distinct is called a villous structure; the shreds are called villi.

The second layer is called the submucous or nervous coat: its thickness is about one-fifteenth of an inch, and it serves to give the requisite strength to the mucous coat, to which it closely adheres. The intestinal glands are seated in the submucous coat: they consist of flat pouches of folded mucous membrane, from two lines in diameter to microscopic minuteness, and are disposed singly and in clusters: each gland opens by a single orifice upon the mucous surface.

The third tunic consists of muscular fibres, of which there are two layers; an inner, disposed in transverse or circular fasciculi; an outer, the direction of which is longitudinal. The inner or circular fibres form with one exception a coat of tolerably equal thickness throughout the whole of the alimentary canal. The longitudinal fibres on the other hand are only well developed towards each extremity. The œsophagus and the rectum have a thick uninterrupted covering of longitudinal fibres, which in the former instance are spread out and lost

upon the stomach, while in the latter they extend the entire length of the colon in the form of three narrow bands: upon the intermediate three-fifths of the whole tube, longitudinal fibres are not constantly found, and when found are but partially distributed along the unattached surface of the bowel, and are so slender in their texture as scarcely to admit of being detached from the peritoneum which covers them.

Between the second and third tunic the cellular membrane is so lax and copious, that it deserves to be described as a separate intestinal coat,—the cellular tunic.

The reason of the unequal disposition of longitudinal fibres upon the alimentary canal I suppose to be this. It is towards the extremities alone of the canal that its contents are of solid consistence; in the central part they are fluid. Now the mode in which the contents of the bowel are propelled is the following: the circular fibres of the part which is to be emptied contract, the fasciculi immediately behind remaining in action to prevent the retrograde passage of the food, those before being relaxed to offer no resistance to its progress. The action of the circular fibres of the bowel is commonly called their peristaltic action; or it is said to be vermicular, from the progressive displacement of the bowel which attends it, resembling the motion of an earth-worm. We may reasonably suppose, that when the peristaltic action is employed in propelling a fluid, which would readily insinuate itself into the next and relaxed portion of the canal, no great strain would be made upon the texture of the part, or more than its elasticity alone would counteract. The case is altered when we consider this action applied to solid substances, such as are the imperfectly masticated food, which is frequently bolted down the œsophagus, or the solid fæces, which are contained in the great intestine: and we recognize at once, in the superadded series of longitudinal fibres in these parts, a provision necessary to prevent their elongation or their rupture.

In the abdomen, the alimentary canal receives a fourth coat from the great serous membrane of that cavity. With partial exceptions, the peritoneum is so attached as to allow the viscera, which it covers, considerable latitude of motion. This provision is of service in facilitating the commodious packing of the viscera in different positions of the body, and during their alternate states of emptiness and repletion; but its

principal object has reference to the peristaltic action of the bowels, which would seem to be imperfectly performed when the portions of the alimentary tube cease to be disconnected with and to have the means of freely moving over each other. Trifling causes are known to produce the severest symptoms of obstruction of the bowels, when the folds of the intestines have become glued together by the effusion of lymph.

The muscular fibres of the alimentary canal seem to receive no direct excitement from the will; accordingly, when the nerves distributed to them are mechanically irritated, no sensible effect follows*: and if a portion of bowel in an animal recently killed is stimulated, the action which follows is not sudden and immediate and confined to the point that was irritated; but it commences after an interval, and gradually extends to some distance along the neighbouring fasciculi. It is probable that the natural stimulus to the action of the bowel is the contact of its contents; and that these, according to their nature, may have a more or less stimulating quality; and that the bowel at different periods, and under different circumstances, may be more or less irritable.

The sensibility of the alimentary canal in the healthy state appears to be very moderate: common sensation is probably limited to the œsophagus, which is supplied by the eighth nerves; and to the extremity of the rectum, which receives nerves from the sacral plexus; the intermediate parts, which are principally supplied with nerves from the sympathetic, appear to have no feeling when handled or even wounded; immoderate distension alone seems capable of exciting pain in these parts in the healthy state.

To take a different, but not less useful, view of the entire alimentary canal, let us next consider it as naturally divided into three parts: 1. The fauces, pharynx, and œsophagus; 2. The stomach and small intestines; 3. The great intestines.

In the first portion, we are conscious of sensation and voluntary action; in the second, these affections are wanting; in the third, they re-appear.

In the first portion the food is prepared for its subsequent elaboration by being rubbed down with saliva to the consist-

* The œsophagus offers an exception to this rule: refer back to chapter iii.

ence of a pulp; in the second, the nutritious element is separated from it; in the third, the refuse matter undergoes some further changes.

The first portion is throughout lined with a fine but distinct cuticle: in the second, the mucous membrane is extraordinarily vascular, and the large and distinct villi which everywhere characterize it, have obtained for the lining membrane of that portion the name of villous coat: the third is remarkable for its plain internal mucous surface, and for the sacculations into which it is thrown through the shortness of the longitudinal fibres.

The series of circular fibres which belong to each of these three leading divisions of the alimentary tube, terminates with it. The circular fibres of the œsophagus are lost upon the cardiac extremity of the stomach: the circular fibres of the stomach and small intestines commence at the fundus of the stomach, and terminate at the valve of the colon: the circular fibres of the great intestine begin at the root of the appendix of the cæcum, and are interrupted only by terminating at the anus.

Finally, each of these portions is characterized by being disproportionately capacious at its commencement: the fauces and pharynx, the stomach, the head of the colon, have a larger internal area than the parts of the tube which immediately follow: near the commencement again of each portion, secretions are most liberally furnished, and the glandular apparatus is more complex: near the fauces are the salivary glands; with the stomach and the first four inches of the small intestines are connected the spleen, the liver, and the pancreas; and the cæcum has a larger share of submucous glands than the colon.

When we turn our attention to the subdivisions of the alimentary tube, we may remark of its whole length, from the fauces downwards, that the two inner coats are apparently more capacious, or have less power of retraction, than the muscular coat which contains them, so that they lie in folds, which have a different character in different parts; these are lessened in proportion as the canal is distended, but never to the extent of becoming obliterated, except perhaps in the œsophagus and the stomach. The plicæ of the inner tunics of the œsophagus are longitudinal; the rugæ in the stomach are disposed with

great irregularity, so as to intercept innumerable areolæ of diversified shapes and sizes; the folds in the small intestine, each a quarter of an inch in depth, are uniformly disposed transversely; they are termed valvulæ conniventes: they never extend quite round the circumference of the bowel: their direction is towards the great intestine: they are so numerous, that each partly covers that below, like tiles upon a roof. The folds of the great intestine appear like sharp circular constrictions.

The stomach is a conical sac, the large end or fundus of which is contained in the left hypochondrium; near this extremity the œsophagus opens by what is termed the cardiac orifice; the stomach crosses the epigastrium, and its narrow end, or pyloric portion, lies in the right hypochondrium. The stomach is braced to the diaphragm by the œsophagus, and to the liver by the lesser omentum and capsule of Glisson, which adhere to its upper and concave edge or lesser curvature: when the stomach becomes distended, it rises by revolving upon its cardiac and pyloric attachments, and presents its unattached convex margin forwards in the epigastrium.

The glands of the stomach are extremely numerous: they are single: they vary in diameter from .02 to .08 of an inch. The largest are towards the fundus, the smaller towards the pylorus. There are none immediately round the cardia, but I have counted forty at the lower part of the œsophagus, disposed in an irregular circle extending a third of an inch above the orifice of the stomach.

The secrètion of the stomach is termed the gastric juice; it has been procured from the human stomach by that spontaneous effort, through which some persons are able without feeling nausea to throw up the contents of the stomach, as well as by exciting nausea and vomiting mechanically in a person who had previously fasted. M. Thenard analyzed small quantities of gastric secretion obtained by the first of these methods: it was found to consist of a large proportion of water, some mucus, and salts of soda and lime; on one occasion the liquid was of an acid nature, on another it was not. "Of this important secretion," observes Dr. Prout, "chlorine in some state or other is an ingredient; it would seem a *necessary* ingredient; for the secretion in its healthy state always contains more or less of chlorine, the powerful influence of which elementary prin-

ciple seems mainly to contribute towards effecting the union of the food with water. The chlorine so indispensable to the reducing process is perhaps more frequently the subject of derangement than any thing concerned with the assimilation of the food. It often happens that instead of chlorine, or a little free muriatic acid, a large quantity of free muriate is elicited. The source of this chlorine or muriatic acid seems to be the common salt in the blood."

Spallanzani describes liquid, which he procured from his own stomach, as frothy and somewhat glutinous, salt to the taste, and not bitter. In investigating its properties, some of this liquid was put into a glass tube with boiled beef that had been masticated: the tube was then hermetically sealed, and exposed near the fire to a considerable heat, though not perhaps exactly equal to the temperature of the stomach. By the side of this tube was placed another, containing the same quantity of flesh immersed in water: the subsequent appearances in both were the following: in twelve hours, the flesh in the former began to lose its fibrous structure, and in thirty-five hours had lost its consistence; to the naked eye it appeared to be reduced to a pultaceous mass, and to have lost its fibrous texture; but a microscope rendered fibres visible. After this semifluid mass had continued two days longer in the gastric fluid, the solution did not seem to have made any further progress, and the reduced fibres were still just as apparent. The flesh did not emit the least bad smell, while that immersed in water was putrid in sixteen hours.

Dr. Fordyce attributes to the gastric secretion, when removed from the body, the same solvent effect which Spallanzani was persuaded it possessed. But others, among whom are M. Montegre and Mr. Thackrah, have asserted the contrary, and the question cannot be considered as finally decided.

A property universally attributed to the gastric juice is that of coagulating albuminous fluids. What is termed rennet consists of an infusion of the digestive stomach of a calf; by adding this to milk, the albuminous part is converted into curd. Dr. Fordyce mentions, that six or seven grains of the inner coat of the stomach infused in water gave a liquor, which coagulated more than a hundred ounces of milk.

There are three methods by which on different occasions the contents of the stomach are expelled. The first is that

which occurs in the ordinary progress of digestion, and consists in the peristaltic action of the circular fibres of the stomach. The second is the spontaneous rejection of food recently taken into the stomach, unattended with nausea and sickness; an effort is made, and the fauces become filled with the recently swallowed food: the effort consists in an exertion of the diaphragm and abdominal muscles, which compress the stomach, at the same time that the fibres of the œsophagus are relaxed, and allow of the retrograde passage of the food. The third instance is vomiting, with nausea and retching.

Vomiting has frequently been supposed to result from an inverted peristaltic action. But as early as 1686 an experiment was made by M. Chirac, which sufficiently proved the true nature of this phenomenon. The experiment was the following: corrosive sublimate was given to a dog upon bread, which was almost immediately thrown up, but nausea and violent retching continued. Upon exposing the cavity of the abdomen, the stomach exhibited a peristaltic motion so feeble as to persuade the operator that the expulsion of its contents could not result from this cause. The wound in the abdomen was then closed: and while the animal continued its efforts to vomit, the finger was introduced and applied to the stomach, which was found to remain free from contraction, and only to be flattened and compressed by the abdominal muscles and diaphragm, at each effort to expel its contents.

Subsequently, several physiologists were inclined to revert to the supposition that the fibres of the stomach are the principal agents in vomiting. Lieutaud and Haller were of this party.

But the following experiments by M. Magendie evince the justness of the original theory of Chirac; they include the mention of an additional fact, which Dr. Haighton had observed, that the division of the par vagum does not prevent vomiting, and present other curious matter for reflection.

If two grains of tartarized antimony dissolved in an ounce and a half of water be thrown into the crural vein of a dog, nausea is produced almost instantaneously; if the stomach is then drawn through a wound in the abdomen, the spasm of retching takes place in the diaphragm and abdominal muscles, but the stomach remains without movement, and no vomiting ensues. If the stomach is then replaced in the cavity of the

abdomen, it may be felt by the finger introduced into the wound to remain relaxed, at the time that its contents are being expelled through the renewed efforts of retching.

If the nervi vagi are divided, and the emetic substance be introduced as above, nausea and vomiting follow.

If the abdominal muscles are removed, leaving the linea alba entire, upon the injection of the emetic substance nausea and vomiting take place, the stomach being compressed between the diaphragm and linea alba.

If the phrenic nerves are divided, and the emetic substance injected, nausea occurs, and vomiting, but more feebly than in the preceding experiment. The diaphragm receives a few twigs from the eleventh and twelfth dorsal nerves, which enable it still to act partially in opposition to the abdominal muscles.

Finally, if the stomach is removed, and a pig's bladder substituted in its place communicating artificially with the œsophagus, the injection of tartarized antimony into a vein is followed by nausea, by retching, and the expulsion of the contents of the artificial stomach into the fauces.

Animals are observed instinctively to swallow a large quantity of air previously to vomiting, which acts like the draughts of liquid prescribed after an emetic by distending the stomach; so that it resists the spasm of the diaphragm and abdominal muscles, and prevents the necessity for their extreme and painful contraction *.

The stomach is remarkable for its sympathies. A blow upon the head produces nausea and vomiting; indigestion produces irritation in the lungs, palpitation of the heart, clouded intellect and depression of spirits; a violent blow on the stomach is instantly fatal.

The valve of the pylorus consists of muscular fibres, that are four times the thickness of the muscular coat of the stomach, and form a strong circular band projecting into the alimentary canal: through the frequent action of these fibres, the pylorus looks as if a piece of packthread had been tied round it. When air is blown into the duodenum in a living animal, it readily finds its way into the stomach: but when blown from the œsophagus into the stomach, the latter submits to a great degree of distension before the pylorus allows the air to pass into the duodenum.

* Mémoire sur le Vomissement.

The small intestines are a tube, the length of which is four times that of the body. A short piece when inflated appears cylindrical, but the bowel is really conical. The small intestine diminishes from the pylorus to the valvula coli, in capacity, in thickness, in vascularity, in the size of the villi, in the depth and number of the valvulæ conniventes. The first portion of the small intestine is termed the duodenum; it is about twelve inches in length, and is closely tied down to the back by the peritoneum, which imperfectly covers it. The duodenum extends first to the right side below the liver, then downwards in front of the right kidney, and then ascends obliquely across the spine towards the left side. The rest of the small intestine, the upper two-fifths of which are termed jejunum, the three lower ileum, is attached to the spine by a deep fold of doubled peritoneum, called the mesentery, which is calculated to allow considerable freedom of motion to the convolutions in which the bowel is disposed. The root of the mesentery extends from the left side of the second lumbar vertebra to near the right groin: the mesentery conveys the vessels and nerves to and from the intestine.

The glands in the small intestine are very numerous; its whole length may be seen by a magnifying glass to contain a prodigious number of the minutest follicles, not collected in groups, but equally scattered throughout. Besides these there are glands of a larger dimension, that present different characters at opposite parts. Near the beginning of the small intestine, especially in the duodenum, the glands of Brunner are situated, which are small flattened lenticular bodies, about a line in diameter, and opening by large orifices. The glands of Peyer are found in the ileum only. They form about thirty groups, for the most part oblong and rounded, rarely triangular, disposed with their long axes parallel to that of the intestine, and situated either upon the unattached margin of the bowel, or at its sides. The length of these groups varies from a few lines to three or four inches. The first are small; they become larger towards the lower part of the ileum.

The villi of the small intestines are larger than those of the stomach; there are about four thousand to the surface of a square inch: their length is about one-fourth of a line; at the upper part of the small intestines they are broader, and frequently shorter, than at the lower part; so that they often form microscopic representations of the valvulæ conniventes.

The small intestine opens into the great intestine, as the œsophagus opens into the stomach, leaving a sort of fundus termed the cæcum upon the left side. At its opening is found the valvula coli, which consists of a production of the ileum in the form of two crescentic flaps, which join at their horns, and are disposed transversely in the great intestine. These flaps contain muscular fibres which are necessary to give effect to the valve. The cæcum varies in length from two inches to six; from its extremity a narrow blind gut, called the appendix cæci vermiformis, is produced.

The first five feet of the great intestine are termed the colon, the cæcum being the caput coli. The colon is distinguished by its capacious size, its epiploïcal appendages, its longitudinal bands, its sacculations; and is divided into an ascending portion, a transverse portion or arch, a descending portion, and a sigmoïdal flexure: the latter terminates in the last portion of the bowel, in length eight inches, which is called the rectum.

The smooth inner membrane of the great intestine, when examined with a magnifying glass, appears everywhere indented or honeycombed with extremely small and shallow fossulæ. The number of mucous glands, either single, or in pairs, or in larger groups, is very considerable.

The last circular fibres of the rectum constitute the internal sphincter of the anus. Without this is another set of fibres of a different character, which are called the external sphincter; they are attached to the bulb of the urethra before, to the os coccygis behind, and are under the control of the will. The anus being a fixed point, when the peristaltic action of the rectum is violent, or the bowel not fixed in its place by a sufficiently firm adhesion to the surrounding parts, it is liable to be thrust in an everted state through the external orifice: when this happens, the longitudinal and circular fibres are everted as well as the mucous and nervous coats.

Mr. Abernethy met with the following curious malformation of the bowels in the body of a boy, which measured four feet three inches in length, was well formed, and had limbs moderately large, yet flaccid, as if wasted by recent disease. The duodenum, jejunum, and ileum, when detached from the body, measured only two feet in length: the great intestines, which were considerably distended, so as to be three inches in diameter, were four feet in length *.

* Phil. Trans. vol. lxxxiii, p. 64.

The fleshy viscera connected with the stomach and small intestines are the spleen, the pancreas, and the liver.

1. The Spleen is a flattened oval viscus, coloured by the blood which it contains, and connected to the fundus of the stomach; its average weight is eight ounces. The splenic artery is large and tortuous, and divides into branches previously to entering the gland, from which five or six small vessels termed vasa brevia are reflected to the stomach. The splenic nerves are derived from the cœliac plexus. It occasionally happens that one or more small glands exactly like the spleen in appearance, are met with in the great omentum below the spleen.

The texture of the spleen is remarkably brittle, and tears like a congeries of membranous cells filled with clotted blood. It appears, however, upon the most careful examination, that cells do not exist in the spleen interposed between the arteries and veins and containing blood. The minute branches of the splenic artery in the substance of the gland divide abruptly into very delicate vessels which have been compared to the hairs of a pencil, and do not anastomose: the veins which encircle them anastomose very freely with each other. Anatomical injections pass readily from the arteries of the spleen into the veins. The spleen contains a great number of soft whitish bodies, of a sixth of a line and upwards in diameter: whether these are cells containing an opaque fluid, or are glandular molecules, is not determined.

It is well known that the spleen may be removed without any serious effect being produced on the system. A dog, from which I removed the spleen, became upon recovering from the wound fatter than before: in a year's time it had returned to its former condition, and no difference was observed in its appearance or habits from those of other dogs: it died about three years afterwards of inflammation of the bowels. On examining its abdomen, the following appearances, which were probably accidental, were remarked. The omentum was loaded with fat, so as to be an inch in thickness at its attachment to the stomach. The left kidney was a trifle larger than the right, and there were two or three large lymphatic glands upon the aorta.

The use of the spleen is unknown: it forms one of a class of parts, that have a texture superficially resembling that of

glands, but want excretory ducts. The parts referred to are the thyreoïd gland, the thymus, and the renal capsules.

2. The Pancreas is an elongated gland, which crosses obliquely the first lumbar vertebra, covering the aorta, and disposed behind the stomach: it generally has two ducts, the larger of which opens into the duodenum, at the same point with the ductus communis choledochus; the smaller either opens into the greater, or into the duodenum at the distance of an inch from the opening of the former. The pancreas weighs from four to six ounces; it is of the same colour and structure as the parotid and submaxillary glands. The pancreatic fluid was supposed to be of the same nature with the saliva; but recent observations have shewn that it contains albumen and a curdy substance. The pancreatic fluid is in a slight degree acid, and holds in solution matters of a saline nature closely resembling those found in all animal fluids.

3. The Liver, placed at the upper part of the abdomen, forms a mass that is in weight not less than four pounds. Independently of its size, the liver is remarkable for the completeness of its excretory apparatus, and still more for the having distributed through it a vein that has the function of an artery.

Or the structure of the liver is percolated not merely by blood from the hepatic artery, but by the venous blood returned from the stomach, from the spleen, from the pancreas, and from the great and small intestines. The coronary veins of the stomach, the splenic and pancreatic veins, and the upper and lower mesenteric veins, unite to form a trunk, called the vena portæ, which enters the liver at its transverse fissure, accompanied by the hepatic arteries, the deep-seated hepatic absorbents, the hepatic nerves, and the hepatic ducts.

In the present treatise anatomical descriptions of parts beyond the merest outline have been rarely introduced; or then only, when they directly elucidate physiology, or happen to have novelty to give them interest. Both these excuses will serve as reasons for my explaining, on the present occasion, the admirable researches of Mr. Kiernan into the structure of the liver.

There are two principal points at which vessels enter or leave the liver; one is the transverse fissure already adverted to, the other is the middle of the posterior edge of the viscus; at the latter point two or three great veins, and several smaller ones,

called hepatic veins, issue, and open into the inferior cava; at the former there enter or escape from the liver the vena portæ, the hepatic artery, the hepatic nerves, the lymphatics, and the ducts: the elements of this quintuple system are distributed throughout the liver together, forming a trunk and branches, wrapped in a loose cellular membrane, which with its contents is termed Glisson's capsule.

It is thus to be understood that there are in the liver two centres of ramification; from the middle of the posterior edge (where they enter) the hepatic veins diverge, subdividing and ramifying in every direction. From the transverse fissure (where they enter) the portal vein with the other elements contained in Glisson's capsule proceeds to ramify; but the branching of the one is disconnected with the branching of the other, the two systems being disposed either at right angles or obliquely to, and decussating, each other.

When a section is made of the liver, these two series of branchings are repeatedly cut through. It is easy to distinguish the one from the other. The section of an hepatic vein is clean: nothing intervenes between the cut vein and the parenchyma of the liver; the coat of the vein is remarkably thin: the vessel has the simple office of conveying the blood that has permeated the liver, out of it. But a section of the vena portæ presents a different character: in the first place the portal vein has thicker coats than the hepatic; but principally and especially is it distinguished by not being cleanly in contact with the parenchyma of the liver; instead of which, it is accompanied by branches of the hepatic artery, of the hepatic duct, by hepatic nerves and absorbents, connected to it and enveloped by the cellular tissue of Glisson's capsule.

Mr. Kiernan's discoveries commenced with his observing a definite relation between the distribution of the vessels in the liver and the two different structures (as they were then thought to be) in its parenchyma. It was believed that the liver contained two distinct elements; one of a yellow colour, the other of a reddish brown; the former bearing the same relation to the other, which the dough of a pudding does to the plums which it contains. The liver was supposed to consist of a general yellow substratum studded with oblong spots of brown. Such indeed is the common appearance which the healthy liver presents, whether its external superficies, or the sur-

face of a section be examined. Mr. Kiernan commenced his observations by noticing that both the brown patches and the interposed yellow matter are fissured in their centre. Then injecting the different vessels with quicksilver, he found, that when the hepatic vein was injected, a thin line of quicksilver appeared in the middle of each of the brown spots; but that, when either the portal vein or the hepatic artery or the duct were the tube injected, fine silver lines showed themselves bisecting the intervening yellow. Thus he determined the end of the hepatic venous system to be in the middle of the brown spots, and the termination of the vessels contained in Glisson's capsule to be in the intervening yellow. It seemed as if in the mechanism of secretion two structures had thus to be penetrated: the portal blood had to make its way first through the yellow matter, then through the brown, before it reached the hepatic vein.

This discovery Mr. Kiernan showed to me, when as yet he had advanced no further; and I recollect the facts seemed to me equally new, and important, and satisfactory. Mr. Kiernan, however, had no thoughts of stopping with establishing the relation so made out. He determined to penetrate, by applying a new principle, those vascular arrangements in the organ, which hitherto had eluded the art of the anatomist. The principle which he employed was the following. He caused animals to die with the liver in a state of anœmia. This was effected by tying the portal vein and hepatic artery an hour before the animal was destroyed. The liver in these animals was found pale and bloodless, and the distinction of different coloured structures was much less apparent. The next step was to inject, in the liver thus prepared, each system of vessels separately and together. The following interesting result was obtained. When red injection was thrown into the hepatic vein alone, the appearance shown in figure 1 was obtained;

Fig. 1.

Fig. 2.

when red injection was thrown into the vena portæ the appearance shown in figure 2 was obtained. Or it now suggested itself to the investigator, and all his subsequent researches have concurred in proving the correctness of the hypothesis, that there are not two structures in the parenchyma of the liver, but one only; and that the ordinary and extraordinary differences of colour, wherewith the liver is mottled, result only from the accidental congestion of one or other of the two opposed vascular systems. The ordinary appearance of a healthy liver resembles that given in figure 1, because in general in death the hepatic veins only are congested. But it is well known that the opposite appearance, resembling figure 2, is sometimes met with, in which little spots of lighter colour are studded in a brown substratum. This it is now evident is the consequence of congestion of the portal system. Sometimes the liver is quite pale; that is because there is no congestion of either system; sometimes the liver is all red, then are both systems congested: sometimes in different parts of the same liver the opposite colouring is met with.

But what is the nature and disposition of the single elementary structure of the liver? what are the integral constituents of this conglomerate? the glandules or lobules of the liver, what are they, how formed, how distinguishable? In other conglomerate glands the glandules are disposed upon the branches of the excretory duct; thus in the parotid and pancreas the duct is seen to perforate the gland, to divide in it, the branches to subdivide, and each subdivision to terminate in a glandule: the gland consists of a branching duct, in the last clustered ramifications of which the secreting vessels are distributed. But in the liver Mr. Kiernan discovered that a different arrangement exists. The glandules of the liver are little conical portions of parenchyma which are formed upon branches of the hepatic veins; their bases are thickly set upon these branches, which are thence called sublobular veins; and each little cone is perforated in its axis by a branch from the sublobular vein, which is thence called the intralobular vein. A glandule of the liver has thus in its axis a branch of the vein by which the blood is to be carried from it: the vessels which carry blood to it, and which take from it its excretory ducts, are disposed around it, clothing it. Or around each glandule a terminal sac of Glisson's capsule is spread as a web, the elements

of which plunge into the glandule, the unused blood being poured off by the central vein.

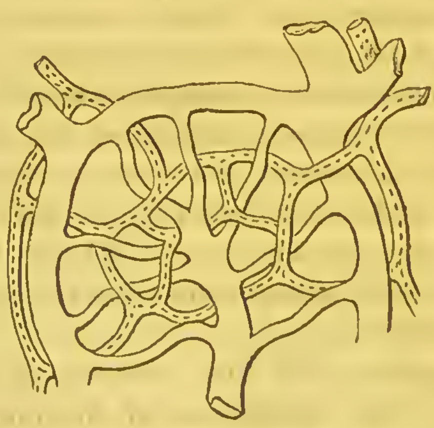
The two following figures represent appearances obtained by slitting up branches of the hepatic or portal veins, and illustrate the account that has been given. Fig. 3 represents the interior of a sublobular vein, or branch of an hepatic trunk; through its thin coats the distinctions of colour are seen of brown spots and yellow substratum; a small point in the middle of each of the former is the commencement of the intralobular vein, or vein of each glandule. On a branch of the vein is represented a section in their axes of three lobules superimposed upon it, with the course of the intralobular vein in the centre of each. Fig. 4 represents a portion of a branch of the vena portæ laid open. Through its thick coats the figure of the lobules is less apparent, and the distribution of colour: still the outline of the lobules can be partially distinguished; enough to show that the small branches of the portal vein, which are given off to be distributed in the hepatic parenchyma, are not given off opposite to the brown spots, or to the centre of the glandules, but to their interstices. The duct and artery are likewise represented participating in the same distribution.

Fig. 3.

Fig. 4.

But what is the structure of each lobule? The following diagram is intended to illustrate it.

Fig. 5.



The large circumferential vessel is supposed to be a terminal branch of the portal vein environing a lobule. Branches

from it are represented as passing through the lobule, and terminating in the central intralobular vein. The figure, however, is strictly a diagram ; in place of a few large vessels *there* represented, in nature there are innumerable capillaries. The vessels in the figure, which are dotted, stand for the commencements of the biliary system. The initial hepatic ducts are a network of fine tubes, of infinite number and reticular complication, involved with, and interposed among the intralobular capillaries. It is supposed that secretion is effected by the transudation of the bile from one vessel into the other, from the capillary into the excretory canals. Thus the hepatic excretory system does not begin in a cell, but in a tubular network. The little biliary tubes I have distinguished by means of dots, because as long as their ramifications can be followed, when laid open, they are seen to be regularly studded with a double row of mucous follicles.

Of the termination of the nerves in the liver, as in other parts, nothing is known with certainty. Mr. Kiernan has thrown more light upon the termination of the hepatic artery. He is of opinion that its branches terminate in the final branches of the portal system. Probably many of them terminate in the intralobular capillaries themselves : thus bringing *all* the blood from the three great azygous branches of the abdominal aorta sooner or later to one and the same termination, namely, to the portal system.

Bile, like all animal fluids, is composed principally of water ; the solid matters contained in the bile are nearly altogether formed from one or more proximate principles, in which carbon and hydrogen predominate. These proximate principles exist simultaneously, if not in conjunction, with soda, and with various salts of soda, besides other substances.

The bile is sometimes green, sometimes of a yellowish brown, sometimes nearly colourless. Its taste is bitter, but not intensely so. It is seldom completely liquid, but usually contains some yellow matter suspended in it. When evaporated to dryness, it leaves a brown matter amounting to about one-eleventh of the original weight.

The bile is perhaps the most complex of all the animal fluids. Besides saline ingredients of the inorganic class, it contains mucus, albumen, osmazome, gliadine, caseïn, picromel,

asparagin, acetic acid, oleïc acid, margaric acid, cholic acid, resin, and colouring matter.

It was thought that the secretion of bile *might* take place from arterial blood. Mr. Abernethy mentions having examined the body of a female infant, which measured two feet in length, and seemed about ten months old. The muscles of the child were large and firm, and covered by a considerable quantity of healthy fat; and the appearance of the body strongly implied that the child had, when living, possessed much vigour of constitution. The liver was of the ordinary size, but had not the usual inclination to the right side of the body; it was situated in the middle of the upper part of the abdomen, and nearly an equal portion of the gland extended into either hypochondrium. The gall-bladder lay collapsed in its usual situation: it was of a natural structure, but rather smaller than common. It contained about a tea-spoonful of bile, in colour resembling the bile of children, being of a deep yellow: it also tasted like bile: it was bitter, but less so than common bile. In this infant (and the case is not a solitary one) the vena portæ terminated in the inferior cava, and the entire supply of blood to the liver was derived through an hepatic artery larger than common.

On the other hand, the recent experiments of M. Simon upon pigeons have shown, that when the hepatic artery is tied, the secretion of bile continues; but that if the portal vein and the hepatic ducts are tied, no trace of bile is subsequently found in the liver: several pigeons survived the latter operation six-and-thirty hours. In these animals it therefore appears that the secretion of bile takes place from venous blood.

M. Simon further observed, that when the hepatic ducts alone were tied, the liver became choked up and filled with globules of a green tint; and that this colour was diffused over the whole surface of the organ, and affected the adjoining parts. It is remarkable, that in from ten to twenty hours after this experiment, the animals discharged by the anus matter absolutely green, and of the colour of the bile, with which the liver was overloaded;—and it seems not unreasonable to suppose that this appearance resulted from a vicarious secretion by the kidneys.

To complete the body of evidence in favour of the opinion

that the bile is necessarily formed from venous blood, Mr. Kiernan found, on examining the preparation of Mr. Abernethy's above referred to, that in it the hepatic artery did not usurp the place of the portal vein: but the portal vein existed as usual, only that it had a blind commencement: its distribution in the liver was the same as usual; the relation of the hepatic artery to it was likewise the same as usual; so that the blood introduced into the liver by the hepatic artery only reached the intralobular capillaries through the portal system, as in naturally formed livers.

SECTION III.

Of the Function of the Stomach.

The progress of the food along the œsophagus is slow but uninterrupted, as we learn when what we swallow has a higher temperature than the blood. The descent of the food depends entirely upon muscular action, so that by practice one may swallow with the head downward. The fibres of the upper part of the œsophagus are observed, in experiments upon animals, to become relaxed directly the food has passed; but those belonging to the lower third of the canal remain firmly contracted for several seconds. M. Hallé remarked in a woman afflicted with a malady which permitted the interior of the stomach to be seen, that at each entrance of food into that cavity the inner membranes of the œsophagus were partially everted, so as to form a prominent circular fold at the cardia. Nothing, however, like a valve exists in human beings at the entrance of the stomach: to supply the place of one, when the stomach is distended, the lowest fibres of the œsophagus are observed frequently to fall into a state of contraction: their action and relaxation likewise keep time in some degree with the breathing; the former generally taking place during inspiration, when the pressure on the stomach is the greatest. The sensations excited in the œsophagus by pressure, laceration, and differences of temperature, exactly resemble those of the skin on similar occasions. This mode of sensibility appears to terminate abruptly at the cardia: the stomach seems to possess nothing of the kind, unless we take as evidence the

sensation of cold, which is referred to the epigastrium, after swallowing liquids at a low temperature.

The first portions of the food that enter the stomach easily find room in its cavity; as more is introduced, that viscus, which when empty was a flattened flaccid sac, great part covered by the liver, now becomes rounded and prominent: as the stomach is fixed at the cardia, pylorus, and lesser curvature, its lower edge rises during its distension and projects in the epigastrium. As the contents of the abdomen during a meal are increased more rapidly than the abdominal parietes are disposed to yield, the different viscera undergo compression; thence the bladder and rectum have a tendency to evacuate what they contain: the descent of the diaphragm likewise has greater resistance offered to it; so that the breathing is shorter, and the exertion of continued speaking or of singing is attended with more than usual effort.

The pylorus is guarded by the contraction of its circular fibres. The food does not, however, on being first swallowed, appear to be equally diffused throughout the stomach; it is detained in the great or cardiac extremity, a third of the length of the stomach towards the pylorus being cut off from the rest by a sort of hour-glass contraction of the circular fibres. Sir Everard Home first described this appearance in the human stomach; its occurrence has since been disputed; but I have met with it in several instances where death had occurred suddenly, while digestion was going on. The food retained in the great extremity of the stomach is slowly dissolved; the solution takes place upon the surface, and in proportion as it proceeds, the dissolved part is rolled off the rest by the peristaltic action of the fibres of the stomach, and carried to the pyloric portion.

All that is swallowed is not digested. By practice one may learn to swallow air, which either soon leaves the stomach, or produces pain and nausea. Plain water, or spirits largely diluted with water, and the like, are readily absorbed without undergoing a previous change. M. Magendie mentions that when a ligature has been tied upon the pylorus in an animal, the disappearance of the aqueous contents of the stomach is not materially retarded by it. Various medicinal substances, whether mineral or vegetable, are directly absorbed or imbibed by the vascular surface of the alimentary canal. The food of some tribes of savages again is partly of a mineral nature. The

Otomacs swallow daily for a season large quantities of an unctuous earth. It is probable, however, that they derive no nourishment from it; and that it only serves mechanically to allay the cravings of their hungry stomachs.

The materials which we digest are furnished by animals and vegetables: the office of the stomach is to convert food of this description into an uniform semifluid mass, which is termed chyme: this change is wrought in human beings, as many experiments have shown, through the exclusive influence of the fluids of the stomach. In proof of the solvent effect of the gastric juice, Spallanzani contrived to throw up, by exciting vomiting mechanically, a tube containing flesh and perforated with holes, which he had swallowed four hours before: the flesh was thoroughly soaked with the fluid of the stomach, and its surface was soft and gelatinous: it had moreover wasted from fifty-three to thirty-eight grains *. Dr. Stevens induced a person practised in swallowing pebbles, to swallow a hollow silver sphere, containing raw or cooked flesh or vegetables, and perforated with holes that would admit a crow-quill: the sphere was voided in about forty hours perfectly empty. Mr. Hunter observed that the splenic portion of the human stomach is found occasionally softened, and even partially or wholly dissolved, after death. In the latter case, the edges of the opening appear pulpy, tender, and ragged; and the parts adjacent to the stomach, the spleen, the diaphragm, and even the lung, are sometimes additionally affected †. No one accustomed to dissection but has verified these observations to a greater or less extent. Dr. W. Philip particularly describes a similar appearance in the stomachs of rabbits, when killed after taking food; and remarks upon the singularity of this occurrence in animals habituated to the digestion of vegetable matter only.

The conversion of the food into chyme is wholly different from the spontaneous resolution which warmth and moisture tend to produce in it. The gastric juice is of an antiseptic nature. Spallanzani ascertained that the gastric juice of the cow and the dog will preserve veal and mutton, and that without loss of weight, for thirty-seven days in winter. And Dr. Fordyce

* Dissertations, &c., vol. i, p. 251.

† Hunter on the Animal Œconomy, p 229.

found that the most putrid meat, after remaining a short time in the stomach of a dog, became perfectly sweet.

The action of the juices of the stomach upon its contents, resembles that of a chemical reagent capable of dissolving them. A morsel of white of egg, for example, after remaining in the stomach, has much the same appearance as if it had been maccrated in weak vinegar or in a solution of potass. According to the notion ordinarily entertained, chyme is an homogeneous greyish pulp, of a sickly sweetish taste, and slightly acid. But it appears likely that there are as many species of chyme as there are of aliments, each having some sensible points of difference from the rest, and retaining other points in common.

In the elaborate experiments of Tiedemann and Gmelin the following differences were observed in the digestion of different principles. The animals chosen for these experiments were dogs and horses. Liquid albumen introduced into the stomach forms a homogeneous fluid, in which the albumen remains quite unaltered ; and this sort of chyme passes the pylorus more rapidly than any other. Coagulated albumen is much more slowly dissolved, and the fluid possesses the properties of coagulated albumen dissolved in acetic acid. Fibrin and vegetable gluten undergo a similar change. Gelatin is converted into a clear brownish fluid, in which neither gelatin nor albumen can be discovered. White cheese forms an opaque, dirty white fluid, containing much animal matter, which however is neither caseïn, gelatin, nor albumen. Starch is gradually dissolved, and loses its reaction with iodine, being converted into sugar and amidine. The results obtained with compound articles of food, such as milk, beef, bread, and oats, in various states of mixture, were such as the foregoing facts would lead one to anticipate. Bones gave a liquid, which contained not only animal matter, but likewise a large quantity of lime. The general result of the whole series of experiments is, that all the animal principles, except liquid albumen, undergo a material change during their solution in the gastric juice, and that the change generally consists in their being made to approach nearer in their nature to albumen *.

The character common to chyme, from whatever kind of food it may have been produced, is its acidulous flavour. Dr. Prout ascertained that the acid generated is the muriatic,

* Edinburgh Medical Journal, No. xciii, p. 369.

both free and in communication with alkalis*. The same conclusion was soon after formed by Tiedemann and Gmelin. They assert the clear ropy fluid of the stomach without food to be nearly or entirely destitute of acidity, while the presence of food or of the most simple stimulus to the mucous membrane, occasions it to become acid, and more so, according to the greater indigestibility of the food. The acid is very copious. They also assert the presence of acetic acid; but Dr. Prout believes this neither necessary nor ordinary, and derived from the aliment when it is observed. Dr. Prout likewise considers the general change of the aliment in the stomach to consist in its greater or less approach to the nature of albumen, but he has been unable to detect true albumen there, when none has been taken †.

The agency of the stomach, viewed as a whole, Dr. Prout observes may be stated as follows. The stomach has the power of *dissolving* alimentary substances, or at least of bringing them to a semifluid state: this operation seems to be entirely chemical, and is probably effected by *reducing* the proportions of these alimentary substances.

By *reduction* Dr. Prout means, the combining of a superfluity of water with the original element, rendering it weaker. Thus fluid albumen is first coagulated (this however is an accident, for gelatin is not): the curdy mass then assumes a gelatinous appearance, till at length the whole becomes nearly fluid. Yet the albumen has undergone no real change. What was introduced into the stomach as albumen is still albumen in the chyme. Yet it has assumed an appearance altogether different: it now coagulates imperfectly, andwants tenacity. It has become chemically combined with a portion of water.

With respect to the powers of conversion possessed by the stomach, Dr. Prout makes the following remarks.

Though the proportions of the different ingredients of the chyle, as ultimately formed, are liable to be much varied according to the nature of the food; yet whatever the nature of the food may be, the general components and character of the chyle remain always the same. The stomach must therefore be endowed with a power or faculty, the agency of which is to secure the uniform composition of the chyle by appro-

* Phil. Trans., 1824, p. 48.

† Elliotson's translation of Blumenbach's Physiology, p. 325.

priate action upon such materials as circumstances may bring within its reach. For indeed, the chief materials from which chyle is formed, namely, the albumens and oleaginous principles, may be considered as already fitted for the purposes of the animal œconomy, without undergoing any essential change in their composition. But the saccharine class of aliments, which form a very large part of the food of all animals (except of those subsisting entirely on flesh), are by no means adapted for such speedy assimilation. Indeed, one or more essential changes must take place in saccharine elements previously to their conversion, either into the albuminous, or into the oleaginous principles. Most probably under ordinary circumstances these essential changes are altogether chemical; that is to say, they are such as do take place, or rather would take place, if the aliments of the substances thus changed in the stomach could out of the body be so collocated as to bring into action the oppositions necessary to produce these changes. Thus the saccharine principle spontaneously becomes alcohol, which is merely an oleaginous body of a weak kind. When therefore in the stomach, it is requisite that sugar be converted into oil, it is probable that the sugar passes through precisely the same series of changes it undergoes out of the body, during its conversion into alcohol. We cannot trace the conversion of sugar into albumen, because we are ignorant of the relative composition and of the laws which regulate the changes of these two substances. The origin of the azote in the albumen is likewise at present unknown to us, though in all ordinary cases it seems to be appropriated from some external source. That the oleaginous principle may be converted into most, if not all the matters necessary for the existence of animal bodies, seems to be proved by the well-known fact, that the life of an animal may be prolonged by the absorption of the oleaginous matter contained within its own body.

Very little gas is found in the stomach during chymification.

M. Magendie gives the analysis by M. Chevreuil of a small quantity taken from the stomach of an executed criminal.

Oxygen	11.00
Carbonic acid	14.00
Hydrogen	3.55
Nitrogen	71.45
	100.00

About four or five hours may be supposed to be the ordinary time in which the conversion of a meal into chyme is effected. M. Richerand mentions that a woman, who had a fistulous ulcer in the stomach at one-third of its length from the pylorus, habitually discharged chyme through the aperture between three and four hours after a meal. She was irresistibly led to remove the dressing from the part at this time. The chyme issued rapidly with a noise and an expulsion of gas. However, the period that chymification takes depends in a great degree upon the nature of the food. According to the observations of M. Magendie, fat, tendon, cartilage, coagulated albumen, mucilaginous and sugary vegetables, resist the action of the stomach longer than fibrinous and glutinous substances. In experiments made by Sir Astley Cooper, fat was found to be digested in the stomach of a dog considerably more rapidly than muscular flesh, than cheese, than skin, cartilage, tendon, or bone, each of which had lost less in weight than the preceding in a given time through the influence of the gastric secretion *.

Imperfect mastication of the food renders the process of chymification slower. Violent exercise or mental excitement immediately after a meal retard its conversion into chyme, and sometimes cause nausea and vomiting. The recumbent posture retards the formation of chyme: sleep retards it: gentle exercise, with a cheerful flow of spirits, promotes it.

As the conversion of the food into chyme proceeds, the sensation of fulness and the disinclination to exertion which ensue upon a hearty meal gradually wear off; and the system recovers from the general languor and oppression of other faculties, which naturally supervene during the commencement of digestion.

In what degree digestion is under the influence of the nervous system is an inquiry that has led to numerous experiments.

It appears sufficiently established, that a meal may be converted into chyme after the nervi vagi have been divided, if their division has been made in such a manner as not to interfere with the functions of other organs besides the stomach.

Sir Benjamin Brodie divided the par vagum upon the cardia,

* Scudamore on Gout, p. 636.

and found that the injury did not prevent the conversion of the food into chyme.

M. Magendie exposed the pneumogastric nerves upon the œsophagus immediately above the diaphragm, after taking out a portion of a rib, and divided them. The animal was then compelled to swallow food, which was converted into chyme, and was found to furnish afterwards an abundant quantity of chyle *.

When, however, the nervi vagi are divided in the neck, the production of chyme has been described as imperfect in those cases wherein it is not entirely prevented; but it is probable that these results ensue indirectly, and are to be attributed to the derangement of other functions. The researches of Dr. W. Philip, confirmed by those of MM. Breschet, Edwards, and Vavassour, tend to make it appear that the galvanic influence directed upon the stomach after the division of the nervi vagi in the neck restores its digestive properties; and that the removal of a portion of each nervus vagus, or the turning away of the ends of the divided nerves, interferes with digestion considerably more than the simple division of these nerves. But whatever light has been thrown upon this subject by the researches of the physiologists I have mentioned, and by the experiments of Mr. Broughton and of Mr. Cutler, we must admit that it yet remains involved in great uncertainty.

MM. Leuret and Lassaigne are among the last who have resumed and varied the experiment of the division of the pneumogastric nerves. *They* state as the result of their inquiries, that the only obvious and necessary effect of the operation is to paralyze the sphincter muscle of the cardiac orifice of the stomach. They found, that when five or six inches of each nervus vagus were cut away in the neck of a horse, and the gullet was tied after the animal had been fed with oats, digestion went on as rapidly as usual: in eight hours one-half of the oats had passed the pylorus; what remained in the stomach was all converted into chyme, and the lacteals were everywhere distended with a white fluid possessing the physical and chemical properties of chyle. This experiment was frequently repeated, and invariably with similar results †.

* Magendie, Elémens de Physiologie, tome ii, p. 103.

† Edinburgh Medical Journal, No. xciii, p. 365.

It appears from experiments by M. Magendie, that when the cerebrum and great part of the cerebellum have been removed in ducks, the instinct of seeking food is lost in every instance, and the instinct of deglutition in many; nevertheless, food that has been introduced into the stomach is found to be digested.

SECTION IV.

Of the Formation of Chyle.

The chyme no sooner collects in the pyloric extremity of the stomach, than it is carried into the duodenum; so that two or three ounces of chyme are the largest quantity ever found in the part of the stomach adjoining the pylorus. Upon watching the manner in which the chyme is carried into the small intestine, a vermicular action is first observed to commence upon the duodenum and gradually to extend itself over the stomach. This having ceased, a new vermicular motion begins upon the stomach itself, which is continued in the opposite direction over the pylorus to the duodenum, carrying the chyme before it. These phenomena are repeated at intervals, and are not observed to be suspended by the division of the pneumogastric nerves.

Upon entering the duodenum the chyme becomes mixed with the bile, the pancreatic secretion, and the mucus of the intestine.

The bile may be seen in living animals to exsude from the ductus choledochus, not continually, but at intervals, a drop appearing at the orifice and diffusing itself over the neighbouring surface about twice in a minute. The pancreatic secretion is yet slower in its elimination *. The bile entering the intestine quickly imparts its sensible qualities to the chyme,—its colour and bitterness. In a short time a spontaneous change is observed to take place in the compound. It commonly separates into a whitish tenacious liquid termed chyle, and a yellow pulp. The former is the recrementitious part of the

* Tiedemann and Gmelin find that the pancreatic secretion contains a very large proportion of highly azotized principles, namely, albumen, caseïn, osmazome, and a matter which is turned red by chlorine.

aliment; the latter, the excrementitious portion, which after undergoing a further change is to be thrown out of the system. Both together are slowly carried along the small intestines, the viscid chyle adhering to the villi, and being detained in the furrows between the valvulæ conniventes; the excrementitious part finally reaching the colon. The chyle gradually disappears in its passage along the small intestines, being absorbed by vessels, which, with their contents, will be described in the following chapter.

The appearance of opaque white tenacious flocculi is however only met with in the contents of the duodenum, when they are derived from the digestion of animal or vegetable matter containing fat or oil. Under other circumstances a viscid greyish substance is found, that forms a layer of greater or less thickness, which adheres to the mucous membrane, and which must be considered as chyle. This difference has been the cause of several mistakes in investigating the source of the chyle.

It is natural to suppose, that the separation of this important substance from the food essentially depends upon its mixture with the peculiar extraneous secretions that are poured into the duodenum. But various facts have been brought forward, which favour a different conclusion. The question is one of the greatest interest; and it has been recently discussed with so much ability in an article in the 93d number of the Edinburgh Medical and Surgical Journal, that I shall not scruple, for the advantage of my readers, to extract at length the observations of the anonymous critic, who appears to me on good grounds to consider some experiments of my own fallacious.

"A few years ago Mr. Brodie was led to infer, from some experiments on the effects of tying the excretory duct of the liver in animals, that the chief purpose of the bile is to separate the chyle from the chyme. For he remarked, that when the choledochus duct was secured with a ligature, and food then given, chymification went on in the stomach as usual, but no chyle could be found in the intestines, or in the lacteals. The lacteals contained a transparent fluid, which he supposed to be lymph, and the watery part of the chyme *. Mr. Brodie's observations have been confirmed by the subsequent experiments of Mr. Herbert Mayo, who remarks, that when the

* Journal of Science and the Arts, xiv, p. 343.

choledochus duct was tied in the cat or dog, and the animal killed at various intervals after eating, 'there was no trace whatever of chyle in the lacteal vessels *.'

"These results are at variance with the experiments both of Leuret and Lassaigne, and of Gmelin and Tiedemann. The former tied the common duct in a dog, and cleared out the intestines by giving it a little castor oil. Twelve hours after the operation they gave it bread and milk with sugar thrice at intervals of six hours; and eight hours after the last meal it was strangled and examined immediately. The stomach contained an acid pulp; a very soft, whitish, sweet-tasted chyme adhered to the villous coat of the duodenum; this matter increased in consistence downwards; and in the great intestines it was firm, but had the same colour, and was nearly destitute of taste or smell. The thoracic duct was distended with a yellowish red transparent fluid, which coagulated on standing exposed to the air, and yielded the usual proportion of fibrin, albumen, and saline matters.

"The experiments of Tiedemann and Gmelin are much more elaborate and precise. They remarked that the animals were attacked with vomiting soon after the operation, then with thirst and aversion to food; on the second or third day the conjunctiva of the eyes became yellow; the stools chalky and very fetid, and the urine yellow and convertible to blue, and then to red, with nitric acid. Some of the animals died; some were killed. Of the latter some had previously recovered from the jaundice, which was owing to a singular phenomenon also noticed by Mr. Brodie in his experiments, the re-establishment of the duct by the effusion of lymph around the tied part, and the subsequent dropping of the ligature. In those in which the biliary duct continued impervious the colouring matter of the bile was found in the blood, the serous membranes, the cellular tissue, the coats of the arteries and veins, and in the fat. Like Brodie, Mayo, and MM. Leuret and Lassaigne, they observed that chymification went on as perfectly as in a sound animal. In the small intestines they found nearly the same principles as in sound animals, with the exception of those derived from the bile; and in particular they found in the duodenum, and in contact with its membrane, the soft

* Medical and Physical Journal for October 1826.

mucous flakes which some physiologists consider, but as our authors imagine erroneously, to be chyle. The contents of the great intestines were likewise, with the exception of the absence of certain biliary principles, the same as in sound animals, but they had an exceedingly fetid and disagreeable odour. The thoracic duct and the lacteals, in animals fed recently before death, always contained an abundant fluid, which was generally of a yellowish colour. It coagulated, like ordinary chyle; the crassamentum acquired the usual red colour; in short, the only difference between it and the chyle seen in a sound animal was, that after the tying of the choledochus duct it was never white. The reason of the difference appears to be, that the white colour is owing to fatty matter, taken up from the food by means of the bile, which possesses the power of dissolving fat, and probably, therefore, aids in effecting its solution in the chyle at the mouths of the lacteals. Mr. Brodie appears to have been misled by the absence of the white colour, which the chyle usually possesses, but which it is well known equally to want in ordinary digestion, if the food does not contain fatty matter. Professors Tiedemann and Gmelin confine the agency of the bile in chylification simply to the accomplishing the solution of the fatty matter*.

"The question, therefore, comes to be, what are really the purposes served by the bile? This question has been fully considered by the Heidelberg professors. They conceive, in the first place, that by its stimulant properties it excites the flow of the intestinal fluids, which is clearly proved to be the case by the unusual dryness of the feces in jaundiced persons, and in animals whose biliary duct has been tied. In the next place, it probably stimulates the intestinal muscles to action. In the third place, considering the abundance of highly azotized principles it contains, it probably contributes to animalize those articles of food which do not contain azote. Fourthly, they believe it tends to prevent the putrefaction of the food during its course through the intestines, because when it is prevented from flowing into them their contents appear much farther

* Dr. Blundell has notes of the cases of two infants, four or five months old, in whom the hepatic ducts terminated blindly; so that no bile entered the intestines, and the stools were white like spermaceti, and the skin jaundiced. But the infants had grown rapidly, and thriven tolerably notwithstanding.—Elliotson's Physiology, p. 339.

advanced in decay than in the healthy state. Fifthly, as already mentioned, it probably tends to liquefy and render soluble the fatty part of the food. But, lastly, they are disposed to consider it also as an important excretion.

"The arguments by which they endeavour to support this opinion, and more particularly to prove that the secretion of bile is supplementary to the function of the lungs, are ingenious, if not conclusive. They first show, from the relative size of the *vena portæ* and hepatic ducts, from the more intimate connection of the biliary capillaries with those of the *vena portæ* than with those of the hepatic artery; and, finally, from the experiments of Malpighi, recently confirmed by those of Simon,—that the bile is a secretion from venous, not from arterial blood. They next prove that a great number of the principles of the bile, such as its resin, colouring matter, fatty matter, mucus, and salts, are thrown out of the body with the feces, in the natural state of the biliary system, or by the urine, and into the cellular tissue, when the excretory duct of the liver is obstructed. These principles all contain a large proportion of carbon, and would appear, therefore, to be intended to carry off the excess of that element which is introduced into the system with the vegetable part of the food, and which is not thrown off by the lungs. In the lungs it is thrown off in a state of oxidation; in the liver it is thrown off chiefly in union with hydrogen, as in the form of resin and fatty matter. That the bile is thus intended to assist the lungs in decarbonizing the blood appears, they conceive, from the following facts. The resin of the bile abounds most in herbivorous animals, whose food contains a great disproportion of carbon and hydrogen. But, what is of more importance, the pulmonary and biliary organs are in different tribes of animals, nay, even in different individuals of the same species, in a state of *antagonism* to one another. The size of the liver and the quantity of the bile are not proportionate to the quantity of food and the frequency of eating; but inversely proportional to the size and perfection of the lungs. Thus, in those warm-blooded animals, which have large lungs, and live always in the air, the liver, compared with the body, is proportionally less than in those which live partly in water. The liver is proportionally still larger in reptiles which have lungs with large cells incapable of rapidly decarbonizing the blood,—and in fishes,

which decarbonize the blood but slowly by the gills,—and above all, in molluscous animals, which effect the same change very slowly either by gills or by small imperfectly developed lungs. It is also worthy of remark, that the quantity of venous blood sent through the liver increases as the pulmonary system becomes less perfect. In the mammalia and in birds the *vena portæ* is formed by the veins of the stomach, intestines, spleen, and pancreas; in the tortoise it receives also the veins of the hind legs, pelvis, tail, and the *vena azygos;* in serpents it receives the right renal, and all the intercostal veins; in fishes it receives the renal veins, and those of the tail and genital organs. Farther, during the hibernation of certain animals of the class mammalia, when the respiration is suspended, and no food is taken, the secretion of bile goes on. Another argument is drawn from the physiology of the fœtus, in which the liver is proportionally a great deal larger than in the adult, and in which the bile is secreted abundantly, as appears from the great increase of the meconium during the latter months of utero-gestation. The last argument is drawn from pathological facts. In pneumonia and phthisis the secretion of the bile, according to the observations of our authors, is increased; in diseases of the heart the liver is enlarged; and in the morbus cœruleus the liver retains its fœtal state of disproportion. In hot climates, too, where, in consequence of the greater rarefaction of the air, respiration is less perfectly carried on than in colder climates, a vicarious decarbonization is established by an increased flow of the bile.

"Besides the bile and pancreatic juice, the chyme receives in the intestines an additional admixture of *mucous,* or other secretions from the intestinal villous membrane. Tiedemann and Gmelin remarked, that in animals which had fasted long, the inner surface of the small intestines was covered with a thin layer of firm mucus, tinged faintly yellow with bile, and that if pebbles or pepper had been swallowed recently before death, a considerable quantity of thinner ropy mucus, and an increased quantity of bile, had been poured out; and Leuret and Lassaigne farther observed, that, when the villous coat of the duodenum was exposed and cleaned, and then touched with diluted vinegar, the membrane immediately exhaled a clear fluid, and the *choledochus* duct discharged much bile and pancreatic juice. It must, however, be evidently almost impos-

sible to acquire a correct idea of the composition and properties of the intestinal secretion, as it cannot be procured free from bile and pancreatic juice. Tiedemann and Gmelin found, that, in animals which had swallowed pebbles while fasting, there was in the intestinal contents more albumen than the pancreatic juice could account for; and Leuret and Lassaigne also found, that the matter adhering to the intestines is in similar circumstances faintly acid. Both believe that it possesses the power of dissolving the food, and Leuret and Lassaigne even give experiments from which they wish it to be inferred, that the intestinal secretions, when mixed with the bile, form a solvent for the food quite as active as the gastric juice, if not even more energetic. But their experiments are unsatisfactory, because in the way in which the intestinal contents were collected they could not fail to be mingled with gastric juice *.

" But whatever may be the agent or agents in the process, it is well known that in their course through the intestines the portions of food which escape chymification in the stomach are gradually altered in nature. The more nutritive articles, such as coagulated albumen, fibrin, caseïn, gelatin, disappear entirely, according to Tiedemann and Gmelin, before they reach the lower end of the ileum, and when any fecula passes the pylorus unaltered, it is converted as in the stomach into sugar and amidine. There is therefore a close analogy between the process of chymification as carried on in the stomach, and the changes which are effected in the small intestines.

" On account of the great number and the complexity of the fluids which are added to the chyme after it reaches the intestines, it is very difficult to determine what precise changes are effected on the food after chymification. The chief facts determined are, that the acidity of the chyme decreases as it passes downwards, and at length disappears long before it reaches the cæcum; that albumen exists abundantly in the duodenum, and decreases rapidly downwards; and that the

* M. Magendie found on introducing a piece of raw flesh into the duodenum of a healthy dog, that in an hour it had been carried to the rectum with no farther change than a discolouration of its surface. Upon fixing a morsel of flesh in the small intestine with a thread, after the lapse of three hours it appeared to have lost about half its weight: the fibrin had been principally removed; what was left was entirely cellular and remarkably fœtid.

caseïn and other highly azotized principles contained in the pancreatic juice also gradually disappear. The disappearance of the acidity of the chyme is partly explained by the admixture of the alkali contained in the bile; the albumen is lost, because it forms an important element of the chyle; and Tiedemann and Gmelin suppose that the other more highly azotized principles go to convert into albumen the unazotized principles in vegetable food,—an idea which derives some support from the fact, that herbivorous animals have a larger pancreas than carnivorous animals, and that a corresponding difference exists between the wild and domestic cat, the former of which lives entirely on animal food, and has the least pancreas.

"The changes wrought on the food in the intestines take place chiefly in the duodenum and upper part of the jejunum. This is shown by the visible properties of the contents of the intestines, and by chemical analysis, and it is farther proved by the gases evolved in the small intestines being produced, according to Leuret and Lassaigne, chiefly, if not solely, in the upper part of their course. These gases, according to the same experimentalists, consist of carbonic acid, azote, and carburetted hydrogen, and are the result, not as some think of putrefaction, but of the chemical changes caused by the digestive process.

"Tiedemann and Gmelin maintain that it is an error to suppose, as some physiologists, and very recently Magendie, have done, that chyle is formed, and may be seen in the intestines. White flakes may be remarked floating in their contents, and adhering to their inner surface, and these have been believed to be the chyle on the point of being absorbed. They are certainly not formed, as has been imagined, by the action of the bile on the chyme, for no such effect is caused by the bile on the chyme out of the body; and on the whole, it appears that they are really nothing else than flakes of thickened mucus. Leuret and Lassaigne, however, affirm, that all the essential principles of the chyle exist ready formed in the chyme. The serous part of the chyle is well known to be present. The fibrinous particles, they say, may also be detected. It is in vain, indeed, to attempt to discover them by chemical analysis; this cannot be done even when chyle is purposely mixed with chyme,—the proportion of other prin-

ciples mixed with them being too great. But if the chyme be attentively examined with the microscope, globules will be found even in the stomach, but much more numerously in the duodenum, which resemble exactly the fibrinous globules of the chyle. That they are in fact nothing else, appears, they think, from their being seen before the microscope to run together and form fine fibrils, and from the absence of such globules in the gastric juice, bile, pancreatic fluid, and intestinal mucus, so that nothing but the food can yield them. If these remarks shall be confirmed, the Parisian physiologists have certainly added an important fact to our knowledge of the process of chylification."

Gas obtained from the small intestines of criminals executed shortly after a repast, was found by M. Chevreuil to contain no oxygen. In the two first cases in the following table, the repast had preceded execution two hours: in the third, it had preceded death four hours.

	Carbonic Acid.		Hydrogen.		Nitrogen.		
1st	...... 24.39	+	55.53	+	20.08	=	100
2d	. .... 40.00	+	51.15	+	8.85	=	100
3d	...... 25.00	+	8.40	+	66.60	=	100

SECTION V.

Office of the Great Intestines.

The changes which take place upon the matter introduced into the colon are a farther absorption of its fluid parts and an admixture with the secretion of the bowel, from which the excrementitious substance derives its fecal odour, which till then is wanting.

Tiedemann and Gmelin observe, that the contents of the alimentary canal, though no longer acid in the lower part of the small intestines, again become acid in the commencement of the great intestine, and are more acid in proportion as the aliment is less digestible. These remarks evidently strengthen the analogy already adverted to, between the stomach and the caput coli. Albumen likewise often reappears in the great

intestine. Dr. Prout found the fluids of the large intestines coagulate lymph even as low as the rectum.

By whatever means absorption takes place from the great intestine, it appears probable that nourishment may be received through this channel. Injections of strong broth into the rectum are known to have proved nutritious. It would be important to ascertain the height to which fluids pass, that are thrown for this purpose into the lower bowels.

The difference of the gaseous contents of the great and small intestines consists in the absence of pure hydrogen from the former: in its place a somewhat smaller proportion of carburetted and sulphuretted hydrogen is found.

I extract from Dr. Prout's inquiries part of a tabular view of the contents of the alimentary canal in dogs fed upon vegetable and animal food, which will serve additionally to illustrate the changes produced in different parts of the great intestine.

VEGETABLE FOOD.	ANIMAL FOOD.
From the Cæcum.	*From the Cæcum.*
Of a yellow brownish colour, and of a thick and somewhat slimy consistence. Did not coagulate milk.	Of a brown colour, and very slimy consistence; smell very offensive and peculiar. Coagulated milk.
A. Water, quantity not ascertained.	A. Water, quantity not ascertained.
B. Combination of mucous principle with altered alimentary matters insoluble in acetic acid, and constituting the chief bulk of the substance.	B. Combination of mucous principle with altered alimentary matters insoluble in acetic acid, and constituting the chief bulk of the substance.
C. Albuminous matter, none.	C. Albuminous matter, a distinct trace.
D. Biliary principle, somewhat altered in quantity, nearly as before.	D. Biliary principle, somewhat altered in quantity, nearly as before.
E. Vegetable gluten? none; but contained a principle soluble in acetic acid, and precipitable very copiously by oxalate of ammonia.	E. Vegetable gluten? none; but contained a principle soluble in acetic acid, and precipitable very copiously by oxalate of ammonia.
F. Saline matters, nearly as before.	F. Saline matters, nearly as before.
G. Insoluble residuum, in small quantity.	G. Insoluble residuum, in small quantity.

VEGETABLE FOOD.

From the Colon.

Of a brownish yellow colour of the consistence of thin mustard, and full of air bubbles. Smell faintish and peculiar, somewhat like raw dough. Did not coagulate milk.

A. Water, quantity not ascertained.

B. Combination of mucous principle with altered alimentary matters, the latter in excess, insoluble in acetic acid, and constituting the chief bulk of the substance.

C. Albuminous matter, none

D. Biliary principle, nearly as before in all respects.

E. Same as in the cæcum.

F. Salts nearly as above.

G. Insoluble residuum, less than in the cæcum.

ANIMAL FOOD.

From the Colon.

Consisted of a brownish tremulous and mucus-like fluid, part with some whitish flakes, somewhat like coagulated albumen, suspended in it. Smell faintish, and not peculiarly fœtid, like bile.

A. Water, quantity not ascertained.

B. Combination of alimentary matter in excess with mucous principle, insoluble in acetic acid, and constituting the chief bulk of the substance.

C. Albuminous matter, none.

D. Biliary principle, nearly as before in all respects.

E. Same as in the cæcum.

F. Salts nearly as above. Only some traces of an alkaline phosphate are observed.

G. Insoluble residuum, a flaky matter in very minute quantity.

VEGETABLE FOOD.

From the Rectum.

Of a firm consistence, and of an olive-brown colour inclining to yellow. Smell fœtid and offensive. Did not coagulate milk.

A. Water, quantity not ascertained.

B. Combination or mixture of altered alimentary matters in much greater excess than in the colon, with some mucus; insoluble in acetic acid, and constituting the chief bulk of the feces.

C. Albuminous matter, none.

D. Biliary principle, partly changed to a perfect resin.

ANIMAL FOOD.

From the Rectum.

Consisted of firm scybala, of a dark brown colour inclining to chocolate. Smell very fœtid. Milk was coagulated by the water in which it had been diffused.

A. Water, quantity not ascertained.

B. Combination or mixture of altered alimentary matters in much greater excess than in either of the other specimens, with some mucus; insoluble in acetic acid, and constituting the chief bulk of the feces.

C. Albuminous matter, none.

D. Biliary principle, more considerable than in the vegetable feces, and almost entirely changed to a perfectly resinous-like substance.

VEGETABLE FOOD.

From the Rectum.

E. Vegetable gluten? none; but contained a principle similar to that in the cæcum and colon.

F. Salts nearly as before.

G. Insoluble residuum, consisting chiefly of vegetable fibres mixed with hairs.

ANIMAL FOOD.

From the Rectum.

E. Vegetable gluten? none; but contained a principle similar to that in the cæcum and colon.

F. Salts nearly as before.

G. Insoluble residuum, consisting chiefly of hairs.

The analysis of human feces, according to Berzelius yields—

Water	73.3
Vegetable and animal remains	7.0
Bile	0.9
Albumen	0.9
Peculiar and extractive matter	2.7
Slimy matter, consisting of picromel, peculiar animal matter, and insoluble residue	14.0
Salts	1.2
	100.0*

As the excrementitious mass descends, it gradually parts with its fluids, becoming towards the rectum particularly dry; it here produces a sensation leading to the desire to expel it, accompanied by an involuntary contraction of the fibres of the bowel. It commonly happens that the peristaltic action of the fibres of the rectum when first distended with fecal matter is opposed by the contraction of the sphincter externus ani; and for the subsequent expulsion of the feces the bowel has again to be thrown into action by an effort of the will.

But we have not grounds for believing that the muscular coat of the bowel is a part that can act voluntarily: all that we know to take place is, that when pressure is made upon the bowel by the diaphragm, abdominal muscles, and levator ani, its peristaltic action recommences.

The longitudinal fibres of the rectum tend to prevent protrusion of the lower part of the bowel, and assist in retracting it from the matter in progress of expulsion.

The frequency with which the lower bowels are emptied depends partly upon habit, partly upon peculiarity of constitution. Heberden mentions a person who naturally had a motion

* Thompson's Chemistry, vol. iv, p. 555.

once a month only, and another who had twelve motions every day during thirty years, and then seven every day for seven years, and rather grew fat than otherwise. In general the accumulation of fecal matter takes place in the rectum daily at the same hour: if the usual time for its evacuation is allowed to pass by, the contents of the rectum appear to be thrown back upon the colon: or at any rate the attempt to evacuate the bowels is fruitless.

SECTION VI.

Of the various Substances employed as Food.

Vegetation seems interposed between the soil and animal life as a chemical apparatus for combining the elements of inert matter into forms, in which they become capable of being assimilated by the animal body to its own nature. Animals again differ among themselves in the original fitness of their organs for digesting vegetable matter; so that some appear to form an intermediate class in reference to the function of digestion, being intended to animalize vegetable matter, while they are themselves prepared by Nature to be the prey of animals exclusively carnivorous. Those which are herbivorous have the alimentary canal considerably more complicated than those which live on animal food; either the stomach is divided into distinct chambers, or the colon and cæcum are remarkably developed to fit them for a more elaborate concoction of the food.

The common food of human beings consists either of muscular flesh and fat, of milk and eggs, or of the seeds of certain grasses, of the roots, the leaves, and stalks of different vegetables, and of various kinds of fruit. But the former substances are found to be more nutritious than the latter; and the greatest bodily strength is attained by combining a diet composed chiefly of animal substance with habits of strong and regular exercise.

The proximate principles of animal matter which serve for nutriment are fibrin, albumen, jelly, oil, caseïn, and osmazome or the extractive matter of meat, which seems to give the spe-

cific flavour to the flesh of different animals, but may possibly consist of fibrin only, slightly altered by heat*.

Gluten, farina, mucilage, oil, and sugar, are the nutritive proximate principles of vegetable matter; at the head of which gluten is placed, as a substance containing nitrogen, and more resembling animal matter than any other proximate principle in plants.

Dr. Prout reduces all the articles of nourishment among the higher animals to three classes, the saccharine, the oily, and the albuminous. The first comprehends sugars, starches, gums, acetic acid, and some other analogous principles; the second, oils and fats, alcohol, &c.; the third, other animal matters and vegetable gluten. The following passage is quoted by Dr. Elliotson in his translation of Blumenbach's Physiology from an unpublished work by Dr. Prout on the subject of digestion.

"Observing that milk, the only article actually furnished and intended by nature as food, was essentially composed of three ingredients, *viz.* saccharine, oily, and curdy or albuminous matter, I was by degrees led to the conclusion that all the alimentary matters employed by man and the more perfect animals, might, in fact, be reduced to the same three general heads; hence I determined to submit them to a rigorous examination in the first place, and ascertain, if possible, their general relations and analogies. An account of the first of these classes, *viz.* the saccharine matters, has been just published in the Philosophical Transactions, and the others are in progress. The characteristic property of saccharine bodies is that they are composed simply of carbon united to oxygen and hydrogen in the proportions in which they form water; the proportions of carbon varying in different instances from about 30 to 50 per cent. The other two families consist of compound bases (of which carbon constitutes the chief element) likewise mixed with and modified by water, and the proportion of carbon in oily bodies, which stand at the extreme of the scale in this respect, varies from about 60 to 80 per cent.; hence, considering carbon as indicating the degree of nutrition, which in some respects may be fairly done, the oils may be regarded in general as the most nutritious class of bodies; and the general conclu-

* Thompson's Chemistry, vol. iv, p. 424.

sion from the whole is, that substances *naturally* containing less than 30 or more than 80 per cent. of carbon are not well, if at all, adapted for aliment.

"It remains to be proved whether animals can live on one of these families exclusively, but at present experiments are decidedly against this assumption, and the most probable view is, that a mixture of two at least, if not of all three of the classes of nutriment is necessary. Thus, as has been stated, *milk* is a compound of this description, and almost all the gramineous and herbaceous matters employed as food by animals, contain at least two of the three. The same is true of animal aliments, which consist, at least, of albumen and oil; in short, it is, perhaps, impossible to name a substance employed by the more perfect animals as food, which does not essentially constitute a natural compound of at least *two*, if not of all *three* of the above three great classes of alimentary matters.

"But it is in the artificial food of man that we see this great principle of mixture most strongly exemplified. He, dissatisfied with the productions spontaneously furnished by nature, culls from every source, and, by the power of his reason, or rather his instinct, forms in every possible manner, and under every disguise, the same great alimentary compound. This, after all his cooking and art, how much soever he may be inclined to disbelieve it, is the sole object of his labour, and the more nearly his results approach to this, the more nearly they approach perfection. Thus, from the earliest times, instinct has taught him to add oil or butter to farinaceous substances, such as bread, and which are naturally defective in this principle. The same instinct has taught him to fatten animals, with the view of procuring the oleaginous in conjunction with the albuminous principle, which compound he finally consumes, for the most part in conjunction with saccharine matter, in the form of bread or vegetables. Even in the utmost refinements of his luxury and in his choicest delicacies, the same great principle is attended to, and his sugar and flour, his eggs and butter, in all their various forms and combinations, are nothing more nor less than disguised imitations of the great alimentary prototype, *milk*, as presented to him by nature."

The following remarkable experiments by M. Magendie, tend to support the views contained in the preceding extract.

A dog fed upon white sugar and water exclusively appeared

for seven or eight days to thrive upon this sustenance. He was lively, and ate and drank with avidity. Towards the second week, however, he began to lose flesh, though his appetite continued good. In the third week he lost his liveliness and appetite; and an ulcer formed on the middle of each cornea, which perforated it, and the humours of the eye escaped: the animal became more and more feeble, and died the thirty-second day of the experiment. Results nearly similar ensued with dogs fed upon olive oil and distilled water; but no ulceration of the cornea took place,—and in dogs fed with gum, and with butter.

A dog fed with white bread made from pure wheat and with water died at the expiration of fifty days. Another fed exclusively on military biscuit, suffered no alteration in its health.

Rabbits or Guinea pigs fed upon one substance only, as corn, hay, barley, carrots, cabbage, &c., die with all the marks of inanition, generally in the first fortnight, and sometimes sooner.

An ass fed upon boiled rice died in fifteen days, having latterly refused its nourishment. A cock lived for many months upon this substance, and preserved its health.

Dogs fed exclusively with cheese, or with hard eggs, are found to live for a considerable period, but become feeble, meagre, and lose their hair.

The substance from which rabbits and Guinea pigs can derive nutriment for the longest period appears to be muscular flesh.

When a certain degree of emaciation has been produced by feeding an animal for some time upon one substance, as for instance upon white bread during forty days, the animal has appetite left to eat with avidity different kinds of food, but the change in diet comes too late; the animal does not regain its strength; it continues to waste, and dies about the same time at which its death would have happened had the exclusive diet been continued.

Or we know empirically respecting our food: that to be nutritious, it must be mixed and varied; that when we are in health, the flesh of adult animals simply roasted, or broiled, is the most wholesome and nourishing element in our meals; that condiments and fermented drinks are in moderation salutary, by stimulating the stomach; that the quantity of liquid at a

meal within certain limits is indifferent and a matter of habit; that it is dangerous suddenly to deviate to any great extent from our established habits in diet; that two or at most three meals are all that the stomach of an adult can well digest in the twenty-four hours.

In sickness every thing is changed. In illness, light food, such as broths and gruel, which would produce disorder and acidity in a strong stomach, often become an essential condition of recovery: just as absolute rest restores a broken bone, which in health it would have weakened.

CHAPTER VI.

OF THE LACTEAL AND LYMPHATIC VESSELS.

We have next to follow the route of the chyle from the small intestines into the venous system.

In the year 1622 Aselli accidentally observed upon the mesentery of a dog a number of white lines extending from the bowel towards the liver: on puncturing them a milk-like fluid escaped, and left them transparent vessels. They were termed lacteals, and were justly supposed by their discoverer to absorb the chyle and to convey it into the blood. Successive inquiries have shown not merely the origin and termination of these vessels, but that they form part of a system as minutely distributed through the frame as the blood-vessels, and theoretically termed the absorbent system.

At the angle formed by the meeting of the subclavian with the internal jugular vein upon either side of the neck, two or more of these pellucid vessels open, so as to pour their contents into the current of blood passing towards the right auricle. These are the main trunks of the absorbent system, which ramifies from the veins of the neck and of the trunk to every region and organ of the body.

The thoracic duct, the largest absorbent vessel in the body, is about three lines in diameter when distended, has a thin but strong texture, and appears when collapsed semi-transparent and of a reddish grey colour. The thoracic duct of a horse, inverted upon the thickest rod it will admit, is shown by the rupture which takes place of its lining membrane to consist of a serous inner tunic and an outer fibrous one. It is presumed that a similar distinction of parts exists in human absorbents*.

Each absorbent vessel contains many valves, consisting of

* Cruikshank, Anatomy of the Absorbing Vessels, p. 1.

pairs of semilunar folds of membrane attached by their convex edges, as in the veins, and capable of being thrown down by the reflux of its contents, so as to prevent their passage in a retrograde direction towards the extreme parts. Upon the fleshy viscera the resistance of the valves may be overcome by continued pressure, so that mercury will pass from a trunk into the branches, which are there found to be distributed arborescently, with a minuteness so surprising, that the surface of the viscus is entirely covered with a reticular sheet of quicksilver. These vessels anastomose with other vessels distributed through the substance of the organ.

In the limbs the absorbent trunks are distributed in two sets; one that accompanies the arteries, another which accompanies the subcutaneous veins: to each artery from three to seven absorbent vessels are attached; with the subcutaneous veins from thirty to fifty are associated, which are spread over the most protected surfaces of the limbs.

At particular parts of the body small flattened bodies circular or oval, from three to ten lines in diameter, are found connected with absorbent vessels. These bodies are termed conglobate or absorbent glands. They are very vascular, and have filaments of nerves distributed to them: each appears to consist of a soft fleshy porous substance contained in a membranous capsule: the central part is whiter and firmer than the rest. Generally many absorbent vessels, termed vasa inferentia, enter a conglobate gland upon the side remote from the heart, and a smaller number, termed vasa efferentia, leave it upon the near side.

Mercury injected into the vasa inferentia is seen to fill a series of cells in the corresponding absorbent gland; it then escapes by means of the vasa efferentia. After an injection with wax, the whole substance of the gland appears to consist of convoluted absorbents irregularly dilated, and which reciprocally communicate.

The situation of the absorbent glands and their connection with the different sets of absorbent vessels is as follows:

Two or three small absorbent glands are found at the inner ancle, four or five in the ham, eight or ten at the groin. To the subcutaneous glands at the groin absorbents tend from the leg and thigh, from the pudenda, the abdominal parietes, the nates, and the loins.

A chain of absorbent glands and a plexus of absorbent vessels ascends around the iliac arteries to the aorta, continually receiving trunks derived from the neighbouring parts. Opposite to the second lumbar vertebra the absorbents of the mesentery, having passed through a cluster of glands, collect into an oval sac termed the receptaculum chyli: the trunk continued from the receptaculum chyli and from the absorbents of the lower extremities is termed the thoracic duct: it ascends between the aorta and right crus of the diaphragm into the posterior mediastinal cavity, which it obliquely traverses from right to left in its course upon the vertebræ to the neck: having perforated the fascia cervicalis profunda, the thoracic duct ascends behind the subclavian artery of the left side, and then arches downwards to open into the angle at which the subclavian vein joins the internal jugular. In this course the thoracic duct is joined by absorbents from the viscera and neighbouring parts. Absorbent glands accompany these vessels; they are particularly numerous around the bronchi, where in adults they are of a black colour.

Two or three absorbent glands are found at the bend of the elbow joint, and clusters of them surround the axillary, subclavian, and carotid arteries. The absorbent vessels of the left side of the head and of the left upper extremity mostly join the thoracic duct, but in part open by two or three separate orifices into the subclavian vein. The corresponding absorbent vessels of the right side open by three or four trunks into the angle at the right subclavian vein and internal jugular: these are sometimes joined by a large branch given off from the thoracic duct in the chest. In the only specimen, in which I have injected this variety, the right branch passed through an absorbent gland.

During the completion of digestion in the small intestines, the absorbent vessels of the mesentery, the receptaculum chyli, and the thoracic duct, are found full of chyle: at other times these vessels contain more or less of a transparent fluid termed lymph, which forms the habitual contents of the remaining larger part of the system.

The absorbent vessels of the small intestines and of the mesentery are termed Lacteals, those in every other part of the body Lymphatics.

Till within these few years, it was the commonly received opinion among anatomists, that the veins and absorbents com-

municated at the points alone which have been already mentioned. To several, indeed, it had happened, when injecting absorbents, to find the mercury run into veins elsewhere; but the circumstance had been considered either as a deviation from ordinary structure, or as the result of some error in the process of injecting. Aselli likewise, the original discoverer of the absorbent system, was persuaded that the lacteals terminated in the vena portæ of the liver: but afterwards, when the direct communication of these vessels with the thoracic duct through the receptaculum chyli had been demonstrated, the supposition of Aselli was considered to be erroneous, and was abandoned. Recently, however, the observations of Fohman have shown that it was partially correct, and that many of the lacteal vessels open into branches of the visceral veins.

The researches of Lippi* go to prove connections between the venous and absorbent system, yet more numerous and general. He has shown that the absorbent vessels in the abdomen open freely into the iliac, the spermatic, the emulgent, the lumbar veins, and the vena cava, as well as into the branches of the portal system: that they communicate both by plunging into the great venous trunks, and by opening into the small veins that issue from the conglobate glands, and by direct continuity with the capillary veins; and, finally, that several absorbent trunks in the belly terminate directly in the pelvis of the kidney;—a fact, which curiously confirms the supposition of Sir Everard Home, that there exists a short route from the stomach to the urinary organs.

Lippi is of opinion, that no communications between the absorbents and the veins take place in the limbs. He observes, "ho poi imprese le injezione più volte dalle estremità inferiori per osservare se mi riusciva riscontrare qualche communicazione di linfatici colle vene degli articoli; ma giammai non sono in questo riuscito." For my own part, I think it not unlikely that such communications do exist. At all events, I have sometimes seen the mercury thrown into absorbents of the limbs unaccountably make its way into the veins.

Mascagni remarked, that on successfully injecting the arteries of a part with size and vermilion, the lymphatics became

* Illustrazioni fisiologiche e patologiche del sistema linfatico-chilifero, del professore Regolo Lippi. Firenze, 1825.

filled with strained size. On injecting the arteries of the mesentery of a dog with ink, I observed the veins next to become filled with a black fluid, and then the lacteals; and I have certainly seen, in one instance, absorbents of the liver filled with coloured injection from the hepatic artery.

Chyle extracted from the thoracic duct of a dog or cat killed while digesting and opened immediately after death, varies in appearance as the food has or has not contained oil or fat: in the former case its colour is milk-white, in the latter it is nearly transparent. Coloured substances mixed with the food are rarely found to impart the least tinge of colour to the chyle.

Chyle is rather heavier than distilled water: it is of a salt taste, and sensibly alkaline. Soon after being drawn it coagulates, and afterward separates into three parts; one solid, which rests at the bottom of the vessel; another liquid; and a third substance forming a thin layer on the surface of the latter, and less observable in the semi-transparent than in the opaque chyle. At the same time the chyle assumes a reddish tint. The solid substance appears to resemble fibrin; the liquid, serum; the third element is of an oily nature. The chyle contains minute globules of various sizes, but the largest are smaller than the particles of the blood.

Chyle formed from the digestion of sugar contains but little fibrin. Dr. Marcet found that chyle derived from vegetable matter contains three times as much carbon as that from animal matter.

Lymph extracted from the thoracic duct of an animal killed after fasting for three or four days is a fluid nearly transparent, slightly opaline, and tinged with red, but sometimes of a yellow tint: of a saline taste: of the specific gravity compared with water of 1022.28 to 1000. From a large dog it may be collected in the quantity of an ounce and a half.

Lymph spontaneously coagulates, and then appears composed of a fibrous clot, in the irregular cells of which a fluid is contained, which on compression again coagulates. The red tint of the lymph is deepened on its coagulation. If the clot be exposed to oxygen it becomes scarlet; if to carbonic acid, purple. Lymph contains globules resembling, but less in size than, those of the blood. According to M. Chevreuil, the composition of lymph is the following:—

Water	926.4
Fibrin	4.2
Albumen	61.0
Muriate of soda	6.1
Carbonate of soda	1.8
Phosphate of lime, Phosphate of magnesia, Carbonate of lime	.5
	1000.0

Prolonged fasting is found to give the lymph of animals a red colour, nearly approaching that of the blood.

The following are the results of the researches of Tiedemann and Gmelin on the nature of the chyle. The firmness of the coagulum of chyle seems to depend chiefly on the quantity of fibrin. Chyle hardly coagulates at all before it has passed through the mesenteric glands. After passing through them, the fibrin begins to appear, and it is much more abundant after the addition of the lymph from the spleen, which contains a very large quantity of fibrin. The quantity is considerably lessened in the chyle of digestion: it is increased in the chyle formed after the ligature of the ductus choledochus. It abounds in the lymph from the lower extremities. In like manner the chyle before passing the mesenteric glands contains no red particles: but it does immediately afterwards, and more particularly after it is mixed with the lymph from the spleen, which abounds with them as with fibrin. These particles are also, like the fibrin, very much diminished in the chyle of digestion, and that proportionally to the nutritiveness and digestibility of the food. They are increased by tying the choledochus duct. They abound in the lymph of the lower extremities. The chyle frequently contains fatty matter,—very little or none, however, if the animal is fasting, or has fed on food which does not contain fat,—and most, when the food is very fatty, when, for example, butter is mixed with it. The fatty matter is not dissolved, but exists merely in a state of minute division and suspension, giving to the chyle its peculiar white colour; for the colour is removed, and the chyle rendered limpid by ether, which carries away the fatty particles. There is no fatty matter in the lymph of the lower extremities; it is much less abundant in the thoracic duct than in the chyle before it passes through the mesenteric glands, and it hardly

exists in the chyle at all when the ductus choledochus is tied. The serum of the chyle is very generally alkaline; in two instances only was it found neutral, namely in a dog fed on fibrin, and in a sheep fed on oats. Its solid contents differ in the chyle of fasting animals and in that of digestion. In the horse while fasting the solid part of the serum consists on an average of 76.2 per cent. of albumen, 6.7 animal matter soluble in water, and 16 animal matter soluble in alcohol; but after digestion, of 61 albumen, 3 animal matter soluble in water, 34 animal matter soluble in alcohol, of which twenty parts were fat. Our authors were not able to decide whether the total amount of solid matter in the serum is increased or diminished during digestion.

The inference drawn by Tiedemann and Gmelin from the foregoing facts is, that the fibrin, colouring particles, and albumen of the chyle, are supplied either not at all by the intestinal lacteals, or at least in much less quantity than by the lymph, which is formed by the blood; and that the food supplies chiefly fatty matter, and other principles soluble in alcohol, particularly osmazome. Before they are entitled, however, to form these conclusions unreservedly, it is necessary to establish a preliminary condition, which they have entirely neglected, namely, that the flow of the lymph increases along with the flow of the intestinal chyle during digestion; for if it does not, then the proportional deficiency of albumen and fibrin in the chyle of digestion, when compared with the lymph, is no proof whatever that the former does not supply even more of these principles than the latter to the blood. The inferior proportion may be more than compensated by the great increase in the whole quantity *.

We may next inquire what facts have been ascertained respecting the commencements of the absorbent vessels. Our knowledge in this instance is of the dubious character which belongs to microscopical evidence, and applies but to the smallest part of the absorbent system: yet it is difficult to distrust the exactness of Cruickshank and William Hunter, and what can be demonstrated of a part, we may infer analogically to be true of the whole.

"A woman," says Mr. Cruickshank, "died in consequence

* Edinburgh Medical Journal, l. c.

of convulsions after lying-in, about five in the morning. She had been in perfect health the preceding evening, and ate heartily at supper. The lacteals (upon the mesentery) were distended with chyle, which here formed a firm coagulum. Many of the villi were so full of chyle that I saw nothing of the ramifications of the arteries or veins; the whole appeared as one white vesicle, without any red lines, pores, or orifices whatever. Others of the villi contained chyle, but in a small proportion; and the ramifications of the veins were numerous, and prevailed by their redness over the whiteness of the villi. In some hundred villi I saw the trunk of a lacteal forming or beginning by radiated branches. The orifices of these radii were very distinct on the surface of the villus, as well as the radii themselves, seen through the external surface, passing into the trunk of the lacteal: they were full of a white fluid. There was but one of these trunks in each villus. The orifices on the villi of the jejunum, as Dr. Hunter himself said (when I asked him as he viewed them in the microscope, how many he thought there might be), were about fifteen or twenty on each villus; and in some I saw them still more numerous *."

Thus it appears that the lacteal system originates by numerous capillary orifices upon the villi of the small intestines; and it is natural to presume that the absorption of chyle commences upon purely physical principles. Accordingly, if the mesentery is exposed immediately after the death of an animal killed during digestion, and the contents of a lacteal are pressed forwards towards the thoracic duct, and a ligature is tied upon the empty vessel, the lacteal is found to become filled again with chyle by the continuance of intestinal absorption. The valves in the larger lacteal vessels are exceedingly numerous. It is reasonable to believe them at least equally numerous in the minute branches in which the system originates. Let us suppose that through capillary attraction, the fluid with which it is bathed would ascend in the capillary orifice of a lacteal;—if it should rise beyond a single pair of valves, the contractile power of the vessel would be sufficient to account for its further progress and final transmission to the veins.

But this simple explanation of the mechanism of lacteal absorption requires to be somewhat modified. Of the nume-

* Cruickshank, Anatomy of the Absorbing Vessels, p. 59.

rous liquid substances which reach the small intestine, chyle only is absorbed by the lacteals.

The experiments of Hunter went indeed to prove the reverse. When a solution of starch and indigo, or milk and water, was injected by Mr. Hunter into the small intestines of sheep and asses, a blueish or whitish liquid appeared to be contained in the lacteals. But there is reason to believe that these observations were not made with sufficient exactness. They have been repeated by M. Flandrin, and various physiologists of the present day; and no substance, thrown into the bowel, distinguishable by its odour, colour, or poisonous effects, could be proved to enter the lacteals. When Mr. Hunter saw a white fluid rise in the lacteals after pouring milk into the bowel, we must therefore suppose that some chyle remained in the small intestine at the commencement of the experiment. Where the blue liquid was used, the deception probably resulted from the following circumstance. When the lacteals upon the mesentery are empty, and are seen against a dusky medium, they have the appearance of blue lines. I observed this circumstance when repeating the Hunterian experiment upon different animals. The lacteals, which when a solution of starch and indigo was first placed in the cavity of the bowel were full of chyle, on being examined half an hour afterwards appeared of a clear blue colour, and those present were for a short time satisfied that the indigo had been absorbed: but upon placing a sheet of white paper behind the mesentery, I found that the blue tinge disappeared,—the vessels were simply empty. On removing the white paper, they reassumed their blue colour.

Thus the repetition of the Hunterian experiment has established a different conclusion to that which its author drew from it, and goes to prove the function of the lacteals to be limited to the absorption of chyle. We are at liberty to conjecture that the orifices of the lacteals have a mode of organic sensibility, which leads them to close on the contact of every other substance. The veins of the mesentery are sometimes found to contain a white fluid, which seems to be chyle: this phenomenon is to be accounted for by the communications between the lacteals and the veins, which Fohman and Lippi have demonstrated.

If the thoracic duct at a proper interval after a meal be exposed in the neck of a dog near its entrance into the subclavian

vein, upon opening the duct chyle escapes with great rapidity. Its velocity is observed to be increased every time that the animal contracts the abdominal muscles, or when the abdomen is compressed by the hand, and to bear a proportion to the quantity of chyme undergoing decomposition in the small intestine. During the first five minutes after opening the thoracic duct in a middle-sized dog, half an ounce of liquid escaped; subsequently the flow of chyle was much slower *.

The use of the conglobate glands is unknown, but they are observed to be disproportionately large, and to contain more fluid, in early life than afterwards.

Of the lymphatic system, beyond the anatomical distribution of its branches, nothing is known with certainty. But we are at liberty to conjecture upon analogy, that lymphatics begin upon the mucous surface of the stomach and great intestines, and that they take up a liquid analogous to the chyle elaborated in those parts from the residue of the food. When indeed a dog is forced to drink diluted alcohol during digestion, the blood has the odour of alcohol, the chyle has not. The blood in the veins of the small and great intestines of the horse is found to have the odour of their contents, which the chyle wholly wants. But on the other hand, MM. Leuret and Lassaigne assert, that *chyle is taken up from the stomach*, and may be found in the lymphatic vessels of that viscus, if an animal be examined soon after digestion has begun.

And we may further conjecture with the Hunters, from the universality of their distribution, and their fabric everywhere similar to that of the lacteals, that lymphatics commence at every part of the body; and that their office is to take up and carry back to the blood those elements of the body which disappear, either to make place for newly secreted matter, or without substitution. This conjecture, at any rate, is the most rational which has been proposed as to the use of the lymphatic system, and is remarkably borne out by various circumstances noticed in disease, of which I shall content myself with citing the most conclusive.

Whenever the flesh becomes impregnated with or imbibes an acrid substance, as for instance the venereal virus, and ulceration follows, the lymphatic system alone suffers sympathetic

* Magendie, Elémens de Physiologie, vol. ii, p. 182.

irritation. The lymphatic vessels in such cases become tender and hardened, or their inflamed state shows itself by red lines upon the skin, or the lymphatic glands inflame, and matter forms around them. But if, during the absorption of a part laden or impregnated with acrid or poisonous juices, one particular set of vessels exclusively becomes irritated, can we doubt that those vessels are the channels of the absorption then going on?

It must after all be admitted that we are very far from possessing a perfect theory of this function. Nevertheless, in the facts which have been adduced in the present and a preceding chapter, there appears to be sufficient evidence to establish the three following propositions.

1. When poisonous substances are applied to an internal and vascular membranous surface, or are introduced into a wound, or by friction upon the surface of the body are forced through the epidermis, so as to enter into and affect the system, they find their way *directly into the blood, through the coats of the blood-vessels* *.

2. The chyle formed during the digestion of the food is taken up from the mucous surface of the intestines by the *lacteals.*

3. When the molecular structure of the body is absorbed, either in the ordinary growth and renovation of the frame, or in the removal of parts which are not at the same time replaced, as happens in ulceration, the *lymphatics* are the agents employed.

* Let me refer the reader to the conclusive experiment by M. Ségalas, mentioned already in connection with the subject of *venous* absorption.

CHAPTER VII.

OF THE URINARY ORGANS.

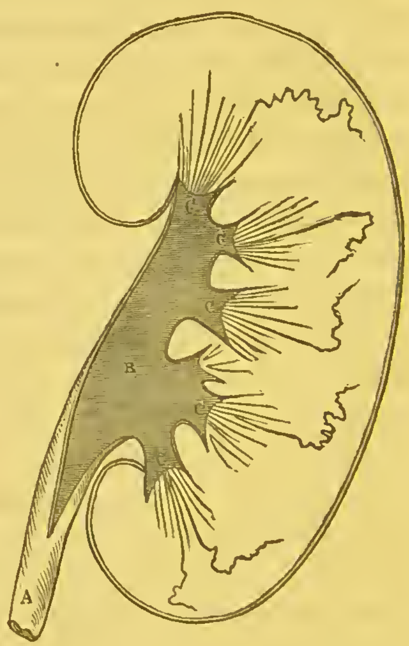
The function of the urinary organs serves, perhaps, better than any other to illustrate a position assumed by physiologists,—that certain principles constantly accumulating in the blood during nutrition require to be as constantly in process of separation from it, in order that it may retain its salutary qualities. In other instances where excretion manifestly takes place, as upon the skin, from the lungs, or from the mucous membrane and glands of the bowels, it may remain a question whether a second object of equal or greater importance be not contemplated: but in the present instance the exclusive use of a very elaborate contrivance appears to consist in getting rid of a superfluous element. As nitrogen exists in a large proportion in the characteristic ingredient of urine, the kidneys are supposed to be the vent at which the excess of this principle is discharged.

The kidneys are placed at the sides of the lumbar vertebræ, before the psoæ and quadrati lumborum, and imbedded in fat. The average weight of the kidney of the adult is four ounces; but there is a considerable variety in this respect, as well as in other circumstances. Sometimes there is but one kidney, which then is of twice the common size. Sometimes both kidneys are situated on the same side. Sometimes the two, being in their natural situation, are united by an isthmus, which stretches across the aorta.

The kidney is a conglomerate gland, and in the fœtus, and occasionally in the adult, is marked by furrows upon its surface which show its internal division into separate lobes. The kidney is covered by peritoneum on the fore part only, its proper tunic is considerably thicker than that of the liver or spleen. Its artery, termed the renal or emulgent, is, relatively to the size of the gland, the largest in the body: it readily transmits injected fluids into the emulgent veins and excretory

tubes. The renal nerves are derived from the semilunar ganglia or solar plexus; several small ganglia are formed upon them: when the renal nerves are divided in a dog, the animal expresses pain.

By making a section from the external convex edge of the kidney through to the internal concave edge, the different substances of which the gland is composed are displayed. The outer or cortical part is of a granulated texture, but seems after a successful injection to consist of tortuous vessels alone; processes of the same substance extend towards the concavity of the kidney, between which are contained cones of what seem white convergent fibres. The rounded apices of these cones project towards the notch of the kidney; they are termed mammillary processes: their surface is perforated with small apertures, through which the urine may be seen to exude in living animals, and the white fibres are excretory tubes, which have their origin in the cortical substance; the mode of their connection with the blood-vessels has not been ascertained. While immersed in the cortical part, that is to say near their origin, the excretory tubes are highly tortuous: in the white cones their course is straight.



Each mammillary process is inclosed in a loose conical sac termed an infundibulum: each infundibulum opens into a common channel, of which there are generally two; one leading from the upper, the other from the lower part of the kidney: these two channels unite to form a capacious conical sac termed the pelvis of the kidney, which gradually narrows, and is continuous with a tube termed the ureter, which is cylindrical, being from three to four lines in diameter when inflated, and leads to the bladder. The infundibulum, pelvis, and ureter, are lined with a fine mucous membrane: their texture is white, fibrous, and of great strength.

The diagram on the opposite page is intended to give a clear idea of the complicated excretory apparatus of the kidney. A represents a portion of the ureter, which traced upwards expands into B, the pelvis, which is figured as if laid open. The pelvis is seen to divide into two canals, from which the conical infundibula, C, open upon the mammillary processes.

The bladder is oviform, the great end looks towards the sacrum and lower opening of the pelvis, and rests upon the levator ani; the narrow end or fundus looks forwards and upwards; the anterior and inferior surface rests upon the pubes; the posterior and upper surface is covered by peritoneum, and the bowels rest upon it. Ligamentous bands, which are the degenerated urachus and hypogastric arteries of the fœtus, attach the sides and fundus of the bladder to the navel. The opening of the bladder into the urethra is at its most dependent part, that is to say, at the lowest part of the greatest breadth of the bladder; the part at which the urethra commences is termed the neck of the bladder; a ligament attaches it to the pubes.

The bladder consists internally of a mucous and submucous coat continuous with those of the ureter; externally of muscular fibres, termed the detrusor urinæ, the inner layer of which is for the most part disposed reticularly; the fibres of the outer layer extend longitudinally from the neck of the bladder to the fundus. The nerves of the bladder are derived from the hypogastric plexus.

The canal of the male urethra, after passing through the prostate gland, from thence forwards to the ligament of Camper is surrounded by a plexus of vessels, and braced to the arch of the pubes by the compressor urethræ of Wilson: the glands of Cowper are placed on either side of the urethra at this part, which is termed the membranous part, and is nearly an inch in length. Beyond the ligament of Camper and from thence to the orifice of the penis, the male urethra is contained in the corpus spongiosum.

The mucous membrane of the urethra does not appear to be an irritable substance; but it is not improbable that the tissue which surrounds it is capable of contracting, in the same manner and on the same principle as the skin. The canal of the urethra is most capacious at the commencement of the spongy body, where it is termed the bulb, and is two parts

surrounded for the length of three or four inches by the fibres of the ejaculator seminis, which are capable of compressing and expelling the contents of the bulb.

The female urethra is short and nearly straight; has no glandular bodies attached to it, but is supported by a compressor urethræ: it is very dilatable.

The urine during health continually varies in quantity and in composition; during cold weather, or when a large quantity of liquid has been received into the stomach, the urine is increased in quantity, and is nearly colourless; during warm weather, when the cutaneous transpiration is greater, less urine is secreted: it is then high coloured, and contains a less proportion of water. Various kinds of food increase the flow of urine, or modify the nature of its constituent parts. The average quantity secreted daily amounts to about four pints.

According to Berzelius, the following is the composition of urine:—

Water	933.00
Urea	30.10
Sulphate of potash	3.71
Sulphate of soda	3.16
Phosphate of soda	2.94
Muriate of soda	4.45
Phosphate of ammonia	1.65
Muriate of ammonia	1.50
Free lactic acid; Lactate of ammonia; Animal matter soluble in alcohol; Urea not separable from the preceding	17.14
Earthy phosphates with a trace of fluate of lime	1.00
Lithic acid	0.32
Silex	0.03
	1000.00

The ultimate elements of urea, according to Dr. Prout, are the following:

Nitrogen	46.66
Carbon	19.99
Hydrogen	6.66
Oxygen	26.66
	99.97

Urine continually exuding into the infundibula of the kidney, urges forward that previously secreted, into the bladder. The ureters open obliquely into the bladder, so that the pressure of the urine accumulating in that viscus, tends to close their vesical termination, and acts as a valve preventing reflux towards the kidneys.

Sir C. Bell has plausibly remarked that the strong muscular fasciculi between the fibres of which the ureters enter the bladder, must contribute during the expulsion of the urine to preserve the valvular obliquity of the entrance by their disproportionate action.

When a certain quantity of urine is contained in the bladder, a peculiar sensation arises, with a desire to void it. By a voluntary effort the levator ani, the abdominal muscles, and the diaphragm contract; and in a few seconds the bladder acts, and the urine flows. There appears to be no necessity for supposing the bladder to be directly influenced by the will. The conscious effort during the expulsion of the urine is not referred to the bladder itself, but to the muscles of the pelvis and abdomen. The fibres of the bladder resemble those of the alimentary canal; when they are pinched immediately after death, a slow contraction of the bladder is observed to begin, which continues for several seconds. When the bladder is laid open by an incision, the contraction which follows the escape of its contents takes place very gradually. I remarked the following remarkable difference between the habitudes of the detrusor urinæ when cut through, and the muscular coat of the intestine. When the latter with the other coats is partially divided, it retracts in such a manner as to produce a gaping wound of the intestine with everted mucous lips. This Mr. Travers pointed out. But when in a living animal, or one but just dead, the bladder is cut into, the lips of the wound fall flaccidly together, and there is no eversion produced.

The compressor urethræ we may suppose to act as the sphincter muscle of the bladder : or that function may be performed by the circular fibres, which sometimes appear very distinct, surrounding the orifice of the bladder within the prostate, and vanishing insensibly into its structure.

One of the most remarkable phenomena in the secretion of urine, is the facility with which substances taken into the stomach find their way to the bladder. Sir Everard Home

observed, that rhubarb could be detected in the urine in seventeen minutes after it had been swallowed. The dose consisted of half an ounce of tincture of rhubarb diluted with an ounce and a half of water, and was taken immediately before a breakfast consisting of tea. The test employed was a solution of caustic potash. Upon an examination of animals to which rhubarb had been given in successive doses for several hours before death, the urine was found deeply tinged, and the serum of the blood in the splenic vein, in the inferior cava, and in the right auricle of the heart, showed evidence of containing rhubarb*. At this time Sir Everard Home was led to believe that the spleen and the lymphatic system were the route through which the rhubarb in the instance cited passed into the blood. But upon renewing these researches at a subsequent period he found, that after removing the spleen and tying the thoracic duct, rhubarb injected into the stomach may be still detected in the urine and in the bile, the contents of the lacteals showing at the same time no trace of rhubarb†.

The facts which have been mentioned contain, it is obvious, the rudiments of the discovery of the imbibition exercised by the blood-vessels. What appears to have thrown into shade the true explanation of the phenomena described, is the difficulty of detecting the element in the blood, during its transit from the stomach into the urine. This anomaly is elucidated in the following observations by M. Magendie.

If a small quantity of prussiate of potash is injected into the veins of a living animal, or is absorbed from a mucous or serous surface, it is quickly and readily distinguishable in the urine, but it cannot be detected in the blood. If, however, the experiment is made with a larger quantity, the presence of prussiate of potash in the blood becomes evident. The same difference M. Magendie observed to exist in the facility of detecting prussiate of potash when mixed with urine and with blood out of the body. In the former case the smallest quantity is discoverable by chemical tests, the action of which is by some means obscured in the latter.

The effect of the excision of the kidneys has been already alluded to. MM. Prévost and Dumas found, that little effect

* Phil. Trans. vol. xcviii, p. 51.

† Phil. Trans. vol. ci, p. 163.

is produced upon the health of a cat or dog by the removal of a single kidney; but that within three days after the removal of the second, copious liquid brown evacuations take place, with vomiting of the same matter, rapid small pulse, great constitutional irritation, and laboured breathing: the animal dies between the fifth and ninth day. MM. Prévost and Dumas calculate that a healthy dog habitually produces about a drachm of urea in twenty-four hours. After the preceding operations had been performed, five ounces of blood were found to contain a scruple of urea*.

M. Magendie observed, that after the removal of the kidneys, the secretion of bile is extraordinarily increased, so that the stomach and intestines are found to contain bile in large quantities.

M. Segalas found that the introduction of urea into the blood of animals operates as a diuretic.

* Anderson's Quarterly Journal, vol. i, p. 294.

CHAPTER VIII.

OF THE SKIN.

THE offices of the skin are so various, that it is difficult to assign to this organ its proper place in a physiological treatise. I have placed it next to the kidney from the relation which one of its functions bears to the function of that part.

The functions of the skin are quintuple. In the first place, the skin is intended to be of such a quality as to bear without injury common pressure or friction; to be sufficiently pliant and flexible to allow of the free motion of the joints and play of the muscles, yet to be so elastic as to make considerable pressure upon and to give support to the soft textures which it covers. In the second place, the skin is to be a means of chemically isolating the body from the influences which surround it; so that all that floats in the atmosphere or comes in contact with the body shall not be indiscriminately absorbed; and on the other hand that the atmosphere shall not abstract and carry away the moisture of the frame too rapidly: or the skin requires to have on its surface some element, which may act, as a layer of India rubber varnish would act, to prevent indiscriminate absorption or evaporation. But thirdly, there are circumstances under which cutaneous absorption is required to take place; the skin has therefore to be viewed as qualified under special circumstances to exercise this function. Fourthly, the skin pours out a most important secretion, the production of which bears a definite relation to the temperature of the body, the range of which it is intended to keep down to the proper standard. Fifthly, the skin is the organ of one of the special senses.

The tough white fibrous tissue, of which the chorion or cutis vera is composed, is well adapted to answer the purposes

specified under the first head. The cuticle or epidermis with which the skin is overlaid answers the purposes of an isolating varnish (the facility with which it is reproduced making up for the loss which it must constantly sustain from abrasion and friction): the epidermal appendages, the nails and hair, contribute again to the first office specified, namely, the protection of the inward parts of the frame. The mechanism of the secretion and absorption which take place in the skin is not so satisfactorily explainable; but the recent and elaborate account of the structure of the skin published by M. Breschet, seems to throw some light upon this subject, and to promise more.

M. Breschet supposes the integument to be formed of two elements only; the true skin, and the epidermis: the intervening layer, or rete mucosum, he considers to be the last secreted layer of epidermis, as yet imperfectly solidified. This view has always appeared to me the most rational that has been offered as to that peculiar substance. The transparent mucus, which is seen when the epidermis of an European is separated by decomposition, is without doubt the same substance with the dark mucous pigment, which is separated in the decomposing skin of the Negro. M. Breschet corrects a common error that the epidermis of the Negro is colourless: the thinner parts of the Negro epidermis are not so, but are tawny: the thickest parts, as at the soles of the feet and palms of the hands, indeed are colourless; at these parts there is less black pigment than elsewhere, the quantity of horny substance formed being much greater than the quantity of colouring matter secreted. The most original points, however, in M. Breschet's paper, refer to orders of vessels, both in the chorion and epidermis, the existence of which was not before suspected. These are to be seen through the following mode of preparing and examining the skin.

The plantar integument of the heel is the part best adapted for the investigation. Having been injected, the skin is to be dried to a very slight degree, enough to give it a firmness, which will allow of an extremely thin slice being cut from the surface of a section: this layer laid on glass previously moistened with water is to be examined in a microscope. It must be so fine as to be transparent. On examining such slices, the appear-

ances delineated in the adjoined figure, according to M. Breschet, may be seen. A represents the papillæ, which are conical, a little oblique, with apices slightly bent, vascular, and well supplied with nervous filaments. B is the colouring organ; this name *(organe chromatogène)* M. Breschet gives to the surface between or surrounding the basis of the papillæ; he describes it as presenting a great number of short excretory tubes; its structure, aréolar; spongy, resistant. I do not, I confess, see evidence enough in his statement for attributing to this surface the exclusive property of furnishing colouring matter to the unorganized integument. C is the organ for secreting the epidermis: this M. Breschet calls *appareil blennogène,* or mucus-secreting part, believing that the epidermis originally is formed as a mucus. The organ supposed to have this office consists of a number of little reddish glands, which are situated near the inner surface of the chorion, and give off excretory ducts, which open in the furrows on the surface of the true skin. M. Breschet concludes, but the conjecture seems to me unsupported by proof, that the primitive mucus out of which the epidermis is to harden is poured out from these sources, being subsequently mixed with colouring matter derived from the organ last described. D represents the sudoriferous canals, which are distinguishable by their tortuousness. Each canal is said to begin in a small sac situated in the substance of the chorion, from whence it spirally winds its way to the epidermal surface, where, instead of being interrupted, it is continued as a fine corkscrew perforation opening upon a visible pore. M. Breschet represents in addition absorbent vessels taking their rise arborescently in the epidermis.

The inner surface of the cutis is hollowed into innumerable shallow fossulæ placed close to each other, and varying in diameter from a twelfth to an eighth of an inch. They receive the subcutaneous layer of fat, upon the quantity of which it depends whether the skin be sleek or wrinkled, and in the same ratio lighter or darker coloured.

The branches of nerves distributed to the skin are derived from the spinal nerves, from the fifth, and from the portio dura of the seventh.

The lymphatics of the chorion are so numerous, that after a successful injection with mercury, the whole surface looks like a sheet of quicksilver: their distribution resembles network more than regular ramification.

The cutis, chemically considered, consists principally of gelatin. The cuticle is a form of coagulated albumen.

a. Isolation.—It is wonderful that so thin a layer of membrane as the epidermis can so effectually prevent both transudation and absorption. How well it serves the first purpose is shown by the different effects of leaving it, and of removing it, from parts of the body after death. When it has been separated, in a few days the flesh dries to the bone: when the cuticle remains entire, no sensible abstraction takes place of the moisture of the body.

b. Absorption.—The epidermis, however, is easily penetrable by moisture from its external surface: it is well known how thick and soft and wrinkled the epidermis becomes after immersion of the hands or feet for some time in water. Nevertheless, how far under these circumstances absolute imbibition of the liquid takes place is very questionable. There are facts which seem to point both ways. But on the whole the evidence rather goes against any sensible absorption through the cuticle taking place as a consequence of mere immersion in a liquid.

Dr. Edwards contrived that a lizard, which had suffered a considerable diminution of weight by exposure to a free current of air for several days, should remain partially immersed in water, which covered its tail, its hind legs, and the hinder part of its body. Under these circumstances the animal reacquired the weight which it had before lost, and its limbs and body regained their plumpness and former volume*.

Dr. Edwards confined a snake in air saturated with moisture, removing it and weighing it at intervals: at first it was found to lose in weight; after a time it ceased to become lighter, and was observed to gain in weight.

M. Seguin observed, that when the human body is immersed in water at a temperature between 12°5 and 22°5 cent, no loss

* De l'Influence, &c. p. 347.

of weight takes place beyond the usual loss by pulmonary transpiration. Immersion therefore in water at the above temperature, must either prevent cutaneous transpiration, or allow an absorption to take place equal to the loss it occasions. The preceding analogies are in favour of the latter solution. But subsequent researches by the same author seem to show, that water in contact with the cuticle of the human body is not absorbed. If the water hold a salt of mercury in solution, it very rarely happens that any evidence of the absorption of the mineral manifests itself even after long and repeated immersion.

The cuticle appears to be the main impediment to cutaneous absorption. When this membrane is removed, absorption takes place rapidly on the exposed surface of the cutis. If by continued pressure, as during the use of mercurial frictions, a substance is mechanically forced through it, absorption readily takes place. Or if a substance which is of an acrid nature, and calculated chemically to unite with it, is placed in contact with the epidermis, a like result ensues. When the foreign matter has passed the cuticle, we must suppose upon analogy that its absorption from the cutis vera takes place through the blood-vessels, not through the lymphatics.

The skin has some action upon the air, which is obscurely understood. Analogy perhaps would lead us to suppose that an absorption of oxygen takes place at the surface of the body; for the experiments of Mr. Cruickshank and of Mr. Abernethy have shown that carbonic acid is produced when the hand or the foot is confined in atmospheric air.

c. Secretion.—A certain quantity of fluid continually escapes by the skin; sometimes this disappears, as fast as it is formed, by evaporation: at other times it collects as a liquid upon the surface of the body. In the former case it is termed the Insensible Perspiration; in the latter the Sensible Perspiration.

The perspiration consists of water containing a small proportion of acetic or lactic acid, of muriates of potash and soda, with a trace of animal matter, apparently gelatin.

The most unexceptionable experiments perhaps relating to the quantity of the insensible perspiration are those of Lavoisier and Seguin. Upon their testimony the average quantity amounts to eleven grains per minute. During digestion the quantity of cutaneous transpiration appears to be at

its minimum. According to Dr. Edwards, during the six hours before noon the insensible transpiration, *cæteris paribus*, attains its maximum. Sleep would seem to promote it remarkably: a dry state of the atmosphere, exposure to a current of air, diminished barometrical pressure, have a similar tendency.

The influences last named are such as would affect the rate of evaporation from a dead body. Dr. Edwards has founded upon these and similar observations, an apparently just division of the elements of the insensible perspiration into such as are derived from secretion, and such as result physically from the evaporation of the moisture of the skin itself. Upon estimating the comparative loss of weight which frogs suffer when placed at a lower temperature in dry air and in air laden with moisture, the proportion of fluid lost by secretion to that lost by transudation appeared to be as 1 : 6*. But it is possible that in dry air the quantity of secretion may be greater than in air laden with moisture; the increase of the demand may increase the quantity of the supply, agreeably with a fact respecting the secretion of milk, which has been already adverted to.

At an elevated temperature and during violent exercise the perspiration becomes sensible. No estimate has been made of the actual quantity of liquid produced under these circumstances, or of the ratio in which the different causes alluded to influence the secretion of the sweat. Sir C. Blagden remarked, that on staying for twenty minutes in a chamber heated to 198° the perspiration was so little increased that his shirt was only damp at the end of the experiment†. A few minutes of violent exercise at a much lower temperature would have produced a copious flow from the skin.

The principal object of the sensible perspiration appears to be the reduction of the temperature of the body. The present occasion, therefore, leads us again to consider the subject of vital heat. Heat, it seems, can be produced in all living beings; but while in plants and cold-blooded animals the temperature closely follows that of the media in which they are immersed, in mammiferous animals and in birds a given temperature is sustained, which is termed their standard heat. In human beings the standard heat is about 97°, in viviparous

* De l'Influence, &c. p. 334. † Phil. Tran. vol. lxv, p. 119.

quadrupeds 100° or 101°: the temperature of birds is yet higher, and rises to 107° or 108°.

Extremes of heat or cold appear temporarily to raise or lower the temperature of the body. After staying sixteen minutes in a dry air at 64° cent., M. Delaroche observed the temperature of the skin to be raised 4°.

During various disorders the temperature of human beings is liable to be raised considerably higher. In fever the heat has been observed to rise to 104°*. M. Prévost witnessed a case of tetanus in which the temperature was elevated 7° cent. above the natural standard. Mr. Cæsar Hawkins mentioned to me his having observed, that in a person who died within twenty-four hours after an injury of the spinal cord at the lower part of the neck, which crushed it, and produced paraplegia, the thermometer applied to the groin ten minutes before death rose to 111°.

The young of warm-blooded animals have a temperature lower than that of adults of the same species. A similar difference has been noticed in the human race. M. Breschet ascertained, upon an examination of ten infants within forty-eight hours after birth, that their temperature varied from 34° to 35°.5 cent.

There appears to be a remarkable difference in the young of warm-blooded animals as to their power of producing heat. A Guinea pig soon after birth is able to resist a low temperature nearly as well as an adult; but kittens and puppies newly-born lose their temperature rapidly when the external heat is artificially lowered ; in a fortnight, however, they acquire the power of evolving heat. This difference bears a relation to the general forwardness of animals. Those which are born with their eyes open, can sustain themselves at a standard temperature : the opposite class resemble at first cold-blooded animals, and their temperature falls with that of the surrounding media. A parallel difference is observed in birds, some of which quickly walk and run upon breaking the egg: these have the temperature of their kind : but others, as for instance the jay, appear hatched before their time, and three or four weeks elapse before they can sustain a standard temperature.

Dr. Edwards, from whose valuable work on the influence of

* Currie's Reports, p. 21, et seq.

physical agents upon the animal œconomy I have largely borrowed in this chapter, gives in connection with the preceding remarks an interesting account of the temperature of a child born at seven months. At this period the existence of the membrana pupillaris ranks the infant with those animals which are born with closed eyelids; and the temperature of the infant in the case alluded to did not exceed 32° cent. although the child was well wrapped up and placed before a fire.

The power of producing heat seems to be different at different seasons. Dr. Edwards artificially exposed five sparrows to the influence of a low degree of temperature during three hours at different periods of the year. In February the heat lost averaged at 0°.4 cent, in July at 3°.62 cent, in August 4°.87 cent. The constitution thus adapts itself to the temperature in which it is placed: when less heat is called for, less heat is habitually produced; and the power of producing it in large quantity is temporarily lost.

Animals that hibernate remain during life unable to sustain a standard temperature against any considerable external cold. In the month of April, the air being at 16° cent, Dr. Edwards exposed a bat to the temperature of 1° for an hour: in this time its temperature fell from 34° to 14°. Adult sparrows and Guinea pigs under corresponding circumstances lost from 2° to 3° only.

Animals of this description on the approach of winter seek to envelope themselves in substances which are calculated to prevent the abstraction of their heat and the free access of the air, and then fall into a torpid state, during which they take no nutriment: their breathing and the circulation of the blood are then so languid, that the performance of these functions has been doubted.

During the torpid state the temperature of the body falls nearly to that of the surrounding media: if the animal is roused, its temperature becomes elevated.

The air of the apartment being 1°.5 cent, the temperature of a torpid bat was 4°. M. de Saissy roused it by mechanically disturbing it. The animal took an hour to wake: at the expiration of thirty minutes its temperature had risen to 15°, when fully roused, to 27°. The temperature of a dormouse under similar circumstances rose to 36°, its standard heat.

It is remarkable that cold serves as a means of waking hibernating animals, not less than mechanical excitement or a high temperature. M. de Saissy carefully exposed a torpid dormouse at a window looking to the north, when the centigrade thermometer stood at 4°. After a period somewhat longer than in the preceding experiment, the animal was roused, and its temperature rose to 36°. But in this instance the cold which wakes the animal from its torpid state becomes quickly fatal; the temperature falls again, and the animal sinks into a lethargy which is mortal.

The hibernating animal is thus liable to perish of cold in the same way as other animals.

In human beings, when sufficient heat cannot be produced to meet the demand from without, the temperature of the body falls, excessive drowsiness and inclination to sleep are felt, which, when yielded to, are fatal. The frame is then in a condition the least calculated to resist the effects of cold; as heat is produced in less quantity during sleep than during waking, during repose than during exercise. Dr. Edwards made the curious remark, that the power of enduring and recovering from the effects of cold in young animals, is inversely as their power of producing heat; so that kittens or puppies newly-born can live for two or three days at a temperature of 20° cent. or even two or three degrees below it*.

The accumulation of heat in the system is not less fatal than its rapid abstraction. Copious perspiration and intense thirst, difficulty of breathing, violent pain in the breast, and palpitation of the heart, followed by insensibility, were the symptoms remembered by one who survived the imprisonment in the black hole at Calcutta. Of one hundred and forty-six who shared these sufferings, twenty-three only outlived one night's confinement in a crowded dungeon during a tropical night†. This great mortality appears to have ensued in consequence of the hot and confined air becoming saturated with moisture, which prevented further evaporation from the skin, and kept the heat of the body permanently raised above the usual standard. M. Delaroche has ascertained by experiment, that animals placed in an atmosphere charged with moisture are unable to

* De l'Influence, &c. p. 474.

† Dodsley's Ann. Reg. 1758.

support a degree of heat that slightly exceeds their standard temperature.

Sir Charles Blagden published some interesting observations on the effects of a high temperature on himself. Upon exposing himself for a few minutes with his clothes on and after a hearty repast to a temperature of 240°, he experienced an oppression upon the chest, attended with a sense of anxiety. He found that his pulse beat 144 pulsations immediately upon leaving the heated room. Upon exposing himself in the forenoon after a moderate breakfast to the temperature of 220° without his shirt, the impression of the heated air was at first painfully disagreeable; but in five or six minutes a profuse sweat broke out, which gave instant relief, and took off all the extraordinary uneasiness: at the end of twelve minutes he left the room very much fatigued, but not otherwise disordered; his pulse had risen to 136*.

* Phil. Trans. vol. lxv, p. 489.

CHAPTER IX.

ON THE FUNCTIONS OF THE NERVOUS SYSTEM.

The offices of the nervous system are of two kinds: on the one hand the brain and nerves exercise a control over the automatic functions of the body; on the other, they form the immediate organs of consciousness.

Viewed in the latter relation, the physiology of the nervous system embraces the two following inquiries: What are the mental endowments of man and animals? Upon what conditions of the bodily organs does their manifestation depend?

SECTION I.

Of the Mental Phenomena in Man and Animals.

I propose in the present section briefly to describe the different affections of the human mind, and to compare them with the mental endowments which animals display. It is difficult not to believe that a common principle of consciousness exists in both; in the one expanded into a reasonable nature, in the other narrowed and subjected to blind impulse and necessity.

Of Sensation and Perception.—When adequate impressions are made upon our organs we are conscious of sensation. When, for example, coloured rays impinge upon the retina, sensations of light are produced in us. *Perception* is a term which in common discourse is used synonymously with sensation: we employ, for instance, indifferently the expressions, to experience sensations of colour, and to perceive colours. But metaphysicians attach different meanings to the words sensa-

tion and perception, using the latter to express the knowledge of the presence and qualities of external objects which follows upon sensation. In order to understand this distinction, it is necessary to analyze the complicated impression which is made upon the mind through the momentary exercise of one organ of sensation. I look, for instance, at an object of such dimensions, that a glance serves to satisfy me respecting its nature. The impression which I receive through the experiment is threefold: comprising, 1. Present sensations of colour: 2. A conviction that those sensations are excited by something external: 3. A knowledge of the real size and form and distance of the object which I have seen. The second of these elements, or the notion which the mind receives of a something external as the cause of sensation, constitutes perception. The third class of impressions that I have described, and which we have learned to associate with the preceding, are our acquired perceptions.

Upon comparing sensation and perception in animals with the like affections in man, it is evident that the former have a partial superiority as to both. Sight in birds generally, and smell in a great variety of animals, are more acute than in man. The sense of smell in animals is closely connected with their most powerful instincts. Its existence and its force may be traced even in creatures of a different caste of organization from ourselves. The aversion, for instance, which bees are said to show to particular individuals is probably to be attributed to the influence of this sense. How far in man as in animals this sense might be used to suggest motives of conduct, is curiously shown in the account by Dugald Stewart of James Mitchell, who had the misfortune to be born deaf and blind, and was thus deprived of the two most important channels through which knowledge is ordinarily received. I may quote the following statement, given upon the authority of Mr. Wardrop.

"When a stranger approached Mitchell, he eagerly began to touch some part of his body, commonly taking hold of his arm, which he held near his nose; and after two or three strong inspirations through his nostrils, appeared decided in his opinion. If it happened to be unfavourable, he suddenly went to a distance with the appearance of disgust; if favourable, he showed a disposition to become more intimate, and expressed by his countenance more or less satisfaction."

With human beings the faculty of perception is of slow growth. Several weeks elapse before we discern intelligence in an infant's gaze, or read in its vacant eye that sensation produces in it a notion of something external. Nor in this case are we wholly to attribute the backwardness of perception to the general imperfection of the infant's mind. In the well-known case recorded by Cheselden, in which by the operation of couching a new class of sensations was suddenly excited in one already grown up and of more than common parts and quickness, correct perception did not immediately follow upon visual impressions, although every other sense was already thoroughly educated, and the understanding ready and bent upon perceiving a familiar world through a new sense. "When this young gentleman," observes Cheselden, "first saw, he was so far from making any judgment about distances, that he thought all objects whatever touched his eye (as he expressed it), as what he felt touched his skin. He knew not one thing from another, however different in shape and magnitude; but upon being told what things were, whose form he before knew from feeling, he would carefully observe that he might know them again."

In animals, the faculty of perception is wonderfully perfect at first and at once.

"As soon as her chickens are hatched," observes Dr. Smith, "the hen carries them to the field to feed, where they walk about at their ease it would seem, and appear to have the most distinct perception of all the tangible objects which surround them. We may often see them accordingly by the straightest road run to pick up any little grains which she shows them, even at the distance of several yards; and they no sooner come to the light than they seem to understand the language of vision as well as they ever do afterwards. The young of the partridge and of the grouse seem to have at the same early period the most distinct perceptions of the same kind. The young partridge, almost as soon as it comes from the shell, runs about among long grass and corn; the young grouse among long heath; and both would most essentially hurt themselves, if they had not the most acute, as well as distinct perception of the tangible objects, which not only surround them, but press upon them on all sides. The young of several sorts of quadrupeds seem, like those of the greater part of birds which make

their nests upon the ground, to enjoy as soon as they come into the world the faculty of seeing, as completely as they ever do afterwards. The day, or the day after they are dropt, the calf follows the cow, and the foal the mare, to the field; and though from timidity they seldom remove far from the mother, they yet seem to walk about at their ease, which they could not do unless they could distinguish, with some degree of precision, the shape and proportion of the tangible objects which each visible one suggests."

Of Volition.—It is easy to imagine a being capable of sensation but wanting every other mental endowment. We may suppose, for example, that plants have sensibility. But it is impossible to prove the conjecture true. Movements in other beings, resembling those which in ourselves are voluntary, constitute our only evidence that they feel.

By volition is here understood the mental attempt to produce muscular action. Under ordinary circumstances its exercise is followed by two effects: certain muscles contract, and their action is attended with some degree of sensation. The mental effort may, however, be complete, yet neither of these consequences follow. There is a disease termed anæsthesia, which consists in the temporary or permanent loss of sensation in the extremities. A patient afflicted with this disorder can move the muscles of his limbs voluntarily; but their action is no longer attended with feeling. The spinal cord is liable to be so injured, as that both motion and sense are extinguished in the lower half of the frame; the sufferer in such a case looks at his palsied limbs, and tries in vain to move them: he is conscious of the perfect mental effort, but neither motion nor sensation follow.

We have no evidence that animals exert volition except in exciting their muscles to contract. In man this faculty has a more extensive operation. We can *will*, not merely muscular exertion, but likewise the direction of the current of our thoughts. Volition in its most comprehensive sense may be defined to be the mental effort to gratify an impulse, or to execute a preconceived intention; or to be the act of the mind which immediately precedes the attempt to gratify an impulse, or to execute a preconceived intention.

Of Instinct.—Besides sensation, perception, and volition, one other element at least is wanted to compose a scheme of

consciousness analogous to our own. Some cause must be found, why voluntary action should occur at one time and not at another, in one class of muscles and not in all at the same moment, and so on. *Motives* must exist to actuate the will.

Upon referring to the ordinary operations of our own minds, volition appears to take place whenever we anticipate a greater degree of gratification or advantage from exerting than from repressing it. We know by experience the prompt influence of the will over our muscular frame: we are able to conjecture with more or less certainty the consequences of different voluntary actions: and we *will*, with a general or precise anticipation of what the result will be, and in order to obtain it. A hungry person knows that the food he prepares to eat will gratify his appetite: a drowning person hopes that his cries will bring people to his assistance. But there are instances in human beings in which intelligent motives cannot be assigned for voluntary actions. The infant at the breast, or struggling when first plunged into water, employs muscular efforts for its sustenance or preservation, no less *voluntary* than those which the schoolboy makes when draining his orange, or the exhausted swimmer when he calls for help. But in the infant, the motive which leads to the voluntary effort, is not the anticipation of pleasure or advantage, but a spontaneous tendency, a blind inclination, an instinct.

Instinct then appears to consist in a natural tendency to execute certain voluntary movements, without any previous conception of the object they are calculated to attain, upon the occurrence of particular sensations or states of inward feeling. This account of instinct corresponds very nearly with the popular meaning of the term. The modifications of this property, as I have described it, are especially characteristic of human and brute intelligence: in man they are subdued and subservient to reason: in animals they greatly surpass in vigour and influence the faint glimmerings of reason which they exhibit, and in some instances curiously rival in their effects the most elaborate results of human thought.

But perhaps it will not be generally granted that instinctive actions are voluntary: let us proceed therefore to examine this question at greater length.

The principal reason for a contrary supposition, consists in our retaining no consciousness of having exerted the will at the

time of their performance. But there are many voluntary actions, which leave no recollection the instant afterwards of an effort of the will having preceded them. I allude to those, which from frequent repetition have become habits. Metaphysicians are generally agreed, that such actions continue to be voluntary, even when the influence of the will in their production eludes observation. We are therefore not authorized to conclude, that instinctive actions are involuntary, merely because we have no recollection of having willed their performance.

Sir Charles Bell attempted to prove that there are different nerves for the transmission of the instinctive and of the voluntary impulse to muscles. But the experimental evidence which he advanced in support of his theory was fallacious. His experiments were made upon the branches of the fifth and seventh nerves, which supply the flesh and integuments of the nostrils and of the lips in the ass. They appear to have been suggested by the following views. The muscles of the face are remarkable for exhibiting at one time instinctive action, as in the play of the features in expression, while at another they are certainly moved by a deliberate effort of the will, as when food is seized with the lips. But the muscles of the face have been thought to be further distinguished from the muscles of most other parts by having two nerves distributed to them, one a portion of the fifth, the other a portion of the seventh nerve. Is it not likely then, reasoned Sir Charles, that one of these nerves (and he chose the seventh) is a nerve *superadded* to minister to that instinctive action so conspicuous in the facial muscles, while the other (the fifth) is the nerve of ordinary qualities, intended to minister in the same parts to sensation and voluntary motion? The error in the experiments by which Sir C. Bell designed to establish his theory lay in this: he overlooked the fact, that, while an animal has two nostrils, it has but one mouth: in other words, while he observed that the muscle which expands the right nostril, is supplied with nerves from the fifth and seventh of the right side alone, he overlooked the fact that the muscle which closes the lips, being disposed with one of its halves on each side of the face, is supplied both by the right and left nerves jointly. Neglecting this difference, Sir C. Bell supposed that he had ascertained the influence of the seventh nerve over the orbicular muscle

of the lips no less than over the muscles of the nostril, when he had divided that nerve on one side only. And as he saw that after the division of one seventh nerve, the nostril on that side ceased to move in breathing (an instinctive action), although the lips continued to be employed in seizing food (a deliberate and voluntary action), Sir C. Bell concluded that he had obtained by this experiment a proof, that *the seventh nerve controls the instinctive actions, but not the voluntary actions of the muscles of the face.* Observing the source of error which I have pointed out, and anticipating that a very different theory of the uses of these nerves would prove to be true, I performed the experiment of dividing the seventh nerve on both sides, and obtained a new result. I discovered by this experiment, that the seventh nerve is the common and exclusive motor nerve of the face; inasmuch as upon its division on both cheeks (the other nerves being untouched) the muscles of the lips as well as of the nostrils are totally paralyzed. They retain indeed under these circumstances sensibility, with which they are endowed by the fifth. Branches of the latter nerve, which emerge from the infra-orbital and mental foramina, to supply the muscles and integuments of the face, Sir C. Bell had supposed to be *nerves both of sensation and voluntary motion.* I discovered that they are exclusively nerves of sensation *.

Thus it appears that upon the face, a part in which the occurrence both of instinctive and of premeditated actions is eminently conspicuous, *one* nerve is proved to minister to this double function. We are authorized in concluding from this fact, that the immediate cause of muscular action is the same in both cases.

There are some occasions upon which actions decidedly

* Mayo's Anatomical and Physiological Commentaries, London, 1822. The reader, who may take a critical interest in this inquiry, should not omit to read Sir C. Bell's *first* essay, printed in the Philosophical Transactions for 1821, in which his opinions are distinctly stated to be such as I have here represented them. In all his subsequent writings on this subject (writings published after the first part of my anatomical and physiological commentaries had in the mean time appeared) Sir C. Bell, retaining the terms which he had employed to explain his theory, such as superadded, respiratory, &c., has substituted for his original opinions my conclusions, I regret to say without acknowledging the source from whence he derived them.

voluntary are substituted for instinctive actions, and the reverse. As an experiment, a physiologist will temporarily alter his rate of breathing, drawing for a period deeper and fewer inspirations than usual, and afterwards reverting to the natural rate. An actor again will at pleasure in an instant throw into his countenance the full expression of mimic passion; directly afterwards perhaps the features subside into their ordinary expression. In these instances there is no effort observed when the change takes place from the one kind of action to another, such as might be expected if different principles were in operation in the two cases.

The instinctive actions, to which I have last adverted, have the following remarkable character in common with those which are consciously voluntary. By an exertion of attention and resolution we can refrain from them; and the constraint which we put upon ourselves, as the effort is more or less successful, closely resembles that commonly experienced upon refraining from the indulgence of those movements which are called habits.

The conclusion towards which the preceding arguments tend has the additional advantage of being intrinsically more philosophical than that to which it is opposed: the first, which classes instinct as a motive to the will, is supported by analogy; the second, which represents instinct as a principle equivalent at once both to motives and volition, disregards all analogy.

I shall now quote one or two examples of the instincts of animals, which may contribute to persuade the reader that instinctive actions are voluntary, and which will at the same time bring us to another disputable question, as to where instinct ends and reason begins. "On dissecting," says Galen, "a goat great with young, I found a brisk embryon, and having detached it from the matrix, and snatched it away before it saw its dam, I brought it into a room, where there were many vessels, some filled with wine, others with oil, some with honey, others with milk or some other liquor, and in others there were grains and fruits. We first observed the young animal get upon its feet and walk; then it shook itself, and afterwards scratched its side with one of its feet; then we saw it smelling to every one of these things that were set in the room, and when it had smelt to them all, it drank up the

milk." What is this but an instance of sensation occasioning a blind impulse to a determinate course of voluntary action?

The next example which I shall adduce, is one of many in which the guiding principle of animals seems at first sight not to be blind, but intelligently to accommodate itself to circumstances, when the ordinary train of action would be unsuitable. "If a hive of bees be this year in possession of a queen duly fertilized, and consequently sure the next season of a succession of males, all the drones, towards the approach of winter, are massacred by the workers with the most unrelenting ferocity. To this seemingly cruel course, they are doubtless impelled by an imperious instinct: and as it is regularly followed in every hive thus circumstanced, it would seem at the first view to be an impulse as intimately connected with the organization and very existence of the workers, and as incapable of change as that which leads them to build cells or to store up honey. But this is far from being the case. However certain the doom of the drones this autumn if the hive be furnished with a duly fertilized queen, their undisturbed existence over the winter is equally sure if the hive have lost its sovereign, or her impregnation have been so retarded as to make a succession of males in the spring doubtful. In such a hive the workers do not destroy a single drone, though the hottest persecution rages in all the hives around them *."

Now how are we to explain this difference of conduct? Are we to suppose that the bees know and reason upon this alteration in the circumstances of their community—that they infer the possibility of their entire extinction if the whole male stock were destroyed when without a queen—and that thus influenced by a wise policy they restrain the fury they would otherwise have exercised? This would be at once to make them not only gifted with reason, but endowed with a power of looking before and after, and a command over the strongest natural propensities, superior to what is expected in a similar case even from a society of men; and it is obviously unwarrantable. The more probable supposition is, that here again the conduct of the animal blindly follows an impulse originating from impressions on the senses: in other words,

* Kirby and Spence's Entomology, vol. ii, p. 501.

that a new instinct is developed, suited to the extraordinary situation in which the community stands, leading the workers now to regard with kindness the drones, for whom otherwise they would have felt the most violent aversion.

But doubtless we may arrive at a point in studying the habits of animals, where instinct yields to other principles. Let us, therefore, proceed to inquire what mental affections are discernible in animals, besides sensation, perception, volition, and instinct, and what effect they have in modifying or superseding the latter.

It is evident that in animals, as in human beings, impressions once traced upon the mind may recur to it. Whoever has observed a dog during its sleep prick its ears and whine, must be persuaded that the animal dreams: in other words, it has the faculty of *conceiving* former objects of sense.

It is not less certain that animals have *memory*: this is shown in the power of personal recognition which they evince.

The principle of *imitation* again exists in various degrees in animals. This principle is one that modifies instinct. A bird untaught will practise from instinct the song of its kind; but placed under circumstances where it hears another song exclusively, the young bird learns the notes in place of its proper song.

Animals display similar principles of mental association with man, and that no less in a wild state than when tamed. The wariness, which wild animals acquire with age, and the education of domesticated animals, sufficiently exemplify this remark.

Animals possess powers of discriminative observation. When you have thrown a ball two or three times in succession for a dog to fetch, if you repeat the gesture of throwing, but retain the ball in your hand, the animal starts headlong after the object you have feigned to throw; but it quickly discovers the deceit: and now, when you would repeat the deception, the animal carefully watches whether the gesture of throwing be real or a feint, before it starts upon its course. A crow will take wing when a person carrying a gun approaches and is yet at a distance, which would allow one without a gun to get within forty yards of it.

It is in instances like the preceding, that animals show the nearest approach to reason. It has thus been observed, that all animals acquire a degree of sagacity with age; that an

experienced greyhound, for example, will in coursing the hare deviate from the direct pursuit of its game, and make straight towards a wood, to turn the hare from gaining its cover. The following singular circumstance, which is to the same purpose, is narrated by Dr. Fleming.

"The hooded crow of Zetland, when feeding on the testaceous mollusca, is able to break some of the tenderer kinds by means of its bill, aided in some cases by beating them against a stone; but as some of the larger shells, such as the buckie and the whelk, cannot be broken by such means, it employs another method, by which, in consequence of applying foreign power, it accomplishes its object: seizing the shell with its claws, it mounts up into the air, and then loosing its hold, causes the shell to fall among stones (in preference to the sand, the water, or the soil on the ground) that it may be broken, and give easier access to the contained animal. Should the first attempt fail, a second or a third are tried, with this difference, that the crow rises higher in the air, in order to increase the power of the fall, and more effectually remove the barrier to the contained morsel."

In both the cases which I have just described, it is not to be doubted that the animal understands that the indirect means which it adopts will lead to the attainment of a desired end; it is hardly possible therefore to call these actions other than rational. At the same time, if the guiding principle in these instances be reason, it must be admitted that its light extends no further than to guide the creature one step in supplying an urgent appetite, and that the general nature of the animal remains irrational still. It is possible that there are beings a grade above us, who look at our prodigies in arithmetical talent in the light in which we view these instances, as partial glimpses in an inferior race of a higher caste of mental faculties.

Perhaps the strongest contrast that can be drawn between the mental nature of animals and man, consists in comparing together the habits of the most intelligent animals under circumstances the most favourable for the improvement of their sagacity, with the mental attainments of human beings when most excluded from the ordinary channels of acquiring knowledge.

The dog, the horse, the elephant, and the monkey, associated frequently with man, and exhibiting almost human sym-

pathies with him, reading his eye, his gestures, yet make no step through their intercourse with him towards a rational nature. Compare all that is most surprising in their acquired character and habits with the following account by Professor Glennie of the poor lad born blind and deaf, to whose case I have before adverted.

"His countenance," as Professor Glennie writes at the time, "notwithstanding his unfortunate defects, does by no means indicate fatuity; nay the lineaments of thought are very observable upon it. His features at times are perfectly composed and sedate. When sensible of the presence of a stranger, or of any object which awakens his curiosity, his face appears animated; and when offended or enraged, he has a very marked ferocity of look. He behaves himself in company with much more propriety than could be expected; a circumstance owing undoubtedly to the great care of his parents, and of his elder sister. He feeds himself. When a stranger arrives, his smell immediately and invariably informs him of the circumstance, and directs him to the place where the stranger is, whom he proceeds to survey by the sense of touch. In the remote situation where he resides, male visitors are frequent, and therefore the first thing he generally does is to examine whether or not the stranger wears boots: if this be the case, he immediately quits the stranger, goes to the lobby, feels for and accurately examines his whip: then proceeds to the stable, and handles his horse with great care, and with the utmost seeming attention. It has occasionally happened that visitors have arrived in a carriage, and on such occasions he has never failed to go to the place where the carriage stood, examined the whole of it with much anxiety, and tried innumerable times the elasticity of the springs. The feeling by which he appears to be most powerfully actuated is curiosity, or an anxious desire to make himself acquainted with every thing that is new to him. He appears to feel affection for those of his family very strongly; discovered extreme sorrow on account of his father's death: laid himself upon the coffin, after his father's corpse was put into it, apparently in much grief; we..t frequently to his grave, and threw himself upon it, whilst he gently patted the turf, and bemoaned himself greatly. He is likewise capable of feeling mirth, and frequently laughs heartily. He is highly gratified by getting new clothes; and as tearing his

clothes is the most usual expression of his anger, so the punishment he feels most is being obliged to wear them after he has torn them.

"Respecting the manner in which he conveys his feelings, I am at a loss to give the information that might be expected. It is certain that those of his family know perfectly in what temper he is, and what he wants to have; and these intimations he conveys to them in the presence of strangers, without these last being sensible of his doing so. When he is hungry, he approaches his mother or sisters, touches them in an expressive manner, and points towards the apartment where the victuals are usually kept. If he wants dry stockings, he points to his legs; and in a similar way intimates his wishes on other occasions. A pair of shoes were lately brought to him, which he found to be too small: his mother then took them, and put them into a small closet. Soon after a thought seemed to strike him, and he contrived to obtain the key of the closet, opened the door, took the shoes, and put them upon the feet of a young lad who attends him, whom they suited exactly.

"His father, when alive, was at much pains in directing him, as his mother still is; but his eldest sister has a much greater power of managing him than any other person. Touching his head with her hand seems to be the principal method which she employs in signifying her wishes to him respecting his conduct: this she does with various degrees of force, and in different manners; and he seems readily to understand the intimation intended to be conveyed. In short, by gratifying him when he acts properly, and withholding from him the objects of his complacency when he has done amiss, he has been taught a sense of what is becoming in manners and proper in conduct, much stronger than it could otherwise be believed that any person in his singularly unfortunate situation could acquire."

But to return from this attempt to compare the mental endowments of animals with our own, to the enumeration of the elements of the human mind, which I proposed to give in this place.

An infant a few months old displays, in common with animals, sensation, perception, instinct, volition, conception, memory, imitativeness, and the power to discriminate between true and false in regard to common objects of sense; the latter

act implies a humble exertion of comparison and judgment; and the dreams of a child, as of a dog, exemplify the working of imagination: and imagination implies, what it operates by, abstraction and recombination. To these mental dawnings the light of reason succeeds,—reflection, the appreciation of abstract truth, the knowledge of right and of wrong, cultivated taste and developed talent.

Attention is the faculty on which reflection is immediately based. We have the wonderful power of fixing our thoughts at pleasure upon any subject of abstract contemplation, and at the same time of allowing the current of our thoughts to glide on, whereby all the light that the comparison of other ideas may throw upon the subject of reflection may be obtained. In truth, in this process the mind must perpetually loose its hold of the subject of attention, and give itself up to accidental trains of thought, being careful only to recover, from time to time, before it has got too distant, the original idea which it is its pleasure at the time to analyze.

Nothing is so difficult as practically to distinguish truth from falsehood, to know what we may believe, what disbelieve: nothing is so important, for we cannot even judge of right but by discriminating what is true. But it is not so difficult to determine the elements of belief, and to assign the different modes in which conviction comes to us. Practically, truth is that which we believe. If a thing be true and we do not believe it, it is not truth to us: if it be false, yet seem to us true, it exerts upon us the moral and intellectual compulsion of truth. But though truth is that which we believe, yet knowing that we may be misled, we form, independently of the belief which we practically entertain, ideas of positive or absolute truth, conceiving that there are propositions which would necessarily command the assent of all, if all the evidence relating to them were laid before us and understood by us. The truths which we admit, or the kinds of evidence which determine our belief, admit of being arranged under three classes, which are the following.

A. Certain truths may be called intuitive; which it will be found, before they have been presented to our minds as definite propositions, were assumed or involved in many of our reflections; and which, as soon as they are put before us as definite propositions, appear of such a nature that we cannot doubt them,

or conceive their negative possible. Of this description are the following.

1. The belief which we entertain of the reality of those mental affections of which we are immediately conscious.

2. Belief in the evidence of memory: in other words, our absolute conviction, when we remember to have experienced an emotion or impression, that we *have* experienced something similar on a former occasion. Our belief in our moral or personal identity is founded on, and proves the force with which the evidence of memory acts on our minds.

3. The belief that space has no limits. This may be brought home to the mind by the following reasoning. If space has limits, let any one imagine them; and having imagined them, let him ask himself what exists beyond them.

4. The belief that duration has no limits. This element of belief, in reference to *past* time, is strikingly put by Cicero in the following passage. "Non enim si mundus nullus erat, sæcula non erant; sæcula nunc dico, non ea, quæ dierum noctiumque numero annuis cursibus conficiuntur. Nam fateor ea sine mundi conversione effici non posse; sed fuit quædam ab infinito tempore æternitas, quam nulla temporum circumscriptio metiebatur, spatio tamen qualis ea fuerat, intelligi potest; *quod ne in cogitationem quidem cadit, ut fuerit tempus aliquod, nullum cum tempus esset.*"—De Nat. Deor. lib. i, sect. ix.

5. The belief that no change can take place without a cause adequate to produce it.

A child, or unlettered person, led by an intuitive perception of this principle, seeks a cause for every phenomenon, and is satisfied that he has found one, as soon as he has discovered a class of parallel cases. The philosopher, analyzing this idea, comes to the conclusion that it is essentially impossible to discover real or *efficient causation;* and that he must ever remain contented with tracing what is constant in the sequences of events, or, as it is termed, *physical causation.* He may discover for instance the conditions agreeably with which the communication of motion by impulse is effected; but he cannot discern any necessary connection in the phenomena. He may measure the force of the attraction of gravity, but he cannot comprehend how that force operates. When he reduces physical causation to its last elements, he determines the physical cause of a phenomenon to be that antecedent which, as far as expe-

rience extends, or reasoning from experience would lead us to expect, has always preceded it, and never takes place without it. The physical law of any class of phenomena he defines to be the expression of the conditions, which invariably attend its occurrence. The further he pursues the investigation, the more clearly he sees that the necessary connection of events must always elude his researches; yet not the less, but the more, does he rest convinced of the existence of such a relation, and persuaded that no change can take place without an efficient cause compelling its occurrence.

Or, our belief with reference to efficient causation will be found to involve three elements.

a. No change can take place without an efficient cause adequate to its production.

b. No efficient cause can take place without the corresponding effect being produced.

c. An efficient cause can act only when and where it exists, and therefore bears a definite relation to time and space.

6. The belief in the existence of an external world bears a close affinity to intuitive truth, inasmuch as it arises spontaneously in our minds, and cannot be seriously questioned by a rational understanding. Yet it must be admitted that we are so constituted, that we can conceive it possible that matter *as perceived by us* has no existence, and that our waking sensations, like those which we seem to experience in a dream, may result from some other cause than present external material impressions.

B. The conclusions obtained by syllogistic, inductive, and mathematical reasoning, command our assent as perfectly as intuitive truths, but in a different way.

a. Syllogistic proof consists in showing that the circumstance you would predicate of an individual has been already granted to belong to the genus.

b. Our belief in a law established by induction turns on a corresponding principle: we have admitted the law before it is stated. The law, which we recognize, is but the general expression of all the instances comprised under it.

c. Mathematical proof rests upon a like basis. The conclusion is shown to be involved in something already admitted.

It is unnecessary to observe, that it does not detract from the ingenuity shown in reducing an argument to the syllogistic

form, or from the genius displayed by the discoverer of a mathematical relation or inductive law, that the conclusion each has come to, is essentially irrefutable.

C. Another mode of belief is founded upon experience and analogy. When we have observed that certain consequences have uniformly followed certain antecedents, we are led by the constitution of our nature to expect the recurrence of those consequences, whenever we see their usual forerunners: thus when we see the sun go down, we entertain no doubt that it will rise on the following morning; and so on in regard to the general order of nature; although it is evidently possible that that order may be interrupted to-morrow.

Our belief in testimony rests upon experience and analogy. The present instance serves remarkably to show the various shades of belief, which may attach to the kind of evidence which we are now considering. Who doubts that Nelson fought at Trafalgar? and who does not doubt the rumour of the day during a period of political excitement? A child that has never been deceived, believes implicitly every assertion made to it. A statesman professes a distrust of history, upon his personal knowledge that it is sometimes falsified.

The questions, upon which our minds are ordinarily employed, are such as are decided by experience and analogy, employed in weighing the value of testimony, and comparing the likelihood of different anticipations. These problems, however, are rarely simple. Another principle is commonly used in their solution. This is the force derived from *cumulative proof*. The impression produced by the superposition of probabilities corresponds with the gradual heightening of terror that is wrought by a skilful combination of incidents in a narrative.

When we bend our thoughts to the serious contemplation of our being and of our duties, it is strongly interesting to observe how far our unassisted reason, using the elements of belief which I have shadowed out, guides us with certainty.

1. We have intuitive knowledge of our mental being, or personal existence.

2. We believe next to intuitively that our present existence is not a dream, but that the na ure that seems without and around us is real.

3. That nature, which we look upon, we are compelled to believe the result not of chance but of contrivance: for we find

everywhere the most striking suitableness of structure and disposition to important objects, that are *so* compassed and attained; — a wonderful harmony and fitness of things, which it is analogically impossible to refer to accident. We attribute therefore the existence of the world, such as we view it, to an intelligent cause,—to the operation of infinite power directed by sovereign wisdom.

4. We observe a prominent character of the designs of nature to be uniformity; we therefore conclude the Author of nature to be One.

5. We desire to know whether He is benevolent or cruel; we look around the world, and we see that happiness is its prevailing character. Nay, that where pain and bodily distress exist, the intervals of suffering convey new sensations of delight, unknown to the more fortunate. We conclude that God is benevolent.

6. We desire to know whether what we esteem goodness characterizes His nature. We observe that all human beings concur in venerating moral excellence. We conclude that that excellence must be part of His nature, who gave the approbation of virtue such deep root in our bosoms.

7. We desire to know His will as to our course of action and life: we find the answer in the profound sentiment of respect for moral order and virtue which He has implanted unalterably in us.

8. We desire to know if our nature is immortal; unaided reason gives us this answer only—It is possible that you are immortals: if you are so, you may be sure that the conduct here, which is most consonant with the will of the Creator, and which the most contributes to rational happiness here, will most contribute to your happiness hereafter. We desire to know why there is evil: what matters it, when we know our duty?

9. We still anxiously bend our thoughts to more certain anticipations of our future being: we feel, as though the Deity, who gave us such aspirations, and such solicitude as to our destiny, should consistently have placed within our reach a distinct announcement of his purposes by us. We have the pages of revelation to turn to, and the scheme of our being is unfolded.

In the preceding argument I have perhaps gone farther than many, who consider that alone to be good which is useful, and rest their conclusions as to the rightness of order and virtue upon the sole ground of their conducing to general happiness. But is there not in our nature a higher impulse towards good? Is there

not within us a moral sense, by which, when not debased, but improved by proper cultivation, we take delight in, and feel warm approbation of acts of good faith, justice, beneficence, piety? The question is one which each must answer for himself.

As the words good and bad exist in the languages of all civilized nations, so likewise we find expressions corresponding with the following—beautiful, sublime, decorous, ludicrous. These expressions bear an application to human conduct or to incidents in human life, without reference to morality. Emotions similar to most of these may be excited in us by the fine arts, or by natural objects. Scenery may be sublime or beautiful: sculpture, painting, acting, and poetry, delight in a similar manner, independently of the imitative pleasure belonging to the three first, and the rarity of the talent displayed in all. As we call the cultivated moral sense Conscience, we term the capacity of receiving delight from the sources I have last described, Taste.

The sketch which I have thus endeavoured to give of the constituent elements of mind would be incomplete without my adverting to diversities of talent, and of temper and disposition, as well as an enumeration of those affections which form the active principles of our nature. We are certainly indebted to Messrs. Gall and Spurzheim, for having thrown into their true prominence in the philosophy of mind, diversities of talent and of disposition, as contrasted with those operations of the understanding which have been already adverted to.

Diversities of talent are diversities in the kind and fertility of mental suggestion. Memory, abstraction, combination, and analogical comparison, are the tools with which all talent works; the means, by which the orator, the sculptor, the poet invent. To all talent the same mental processes are necessary: but the orator is not convertible into the sculptor, the painter into the poet: the classes of association which each wields is peculiar. The difference of talent is in the subjects which it feels and can operate on, not in its mode of operating.

The justness of this manner of viewing the subject is borne out by what we know of early prodigies of partial talent. The most remarkable instances perhaps are to be found in the faculty of arithmetical calculation which some are endowed with, and in which the most wonderful powers of analysis and combination are shown, but in reference to numerical relations alone. In these we learn, that the gifted individual has

enjoyed from early childhood an intuitive perception of the properties of quantities themselves; that rules for facilitating complex arithmetical calculations spontaneously present themselves to his mind; that he has an instantaneous perception of the best among several modes of performing the same operation. One, who gave to a friend of mine this account of his own powers, stated at the same time that his mental multiplication table reached to 1000, a remark which seems to me to throw light upon the nature of this extraordinary talent, or to show it to be the same in kind, though incomparably superior in rapidity, to that which common persons may command by practice. It is but in its extent, facility, and rapidity of combination, that genius differs from ordinary ability.

To conclude this enumeration of the principles of our nature, I have to mention those shades of character, which constitute diversities of temper and disposition: for this purpose I shall content myself with setting down the different epithets by which these are known. They are the following:—one may be irascible or cool, hasty or deliberate, cheerful or morose, steady or volatile, even or uneven, sanguine or gloomy, irritable or phlegmatic, enthusiastic or saturnine, vindictive or placable, active or indolent, bold or timid, ingenuous or artful, compassionate or unfeeling.

Finally, the active principles of our nature, are, 1. Our instincts, the desire of gratifying the appetites, the desire of self-preservation, curiosity, and the principle of self-esteem. 2. Regard for the opinion of the world, emulation and envy, the love of power, personal liking and aversion, fear, anger, sympathy, imitation.

These are termed active principles, because they produce in us an inclination to action; it is evident that others remain to be enumerated: whatever is pleasing or displeasing strikes upon an active principle of our nature. We court change, we are pleased with what is new, and yet we are pleased with what has become habitual: we seek to gratify our taste, and our moral feelings; and the exertion of talent, like the indulgence of our humour, is a source of direct pleasure.

But what then is the mind, the possessor of these powers, the subject of these numerous affections and shades of humour? All that we know of it, is contained in the brief history of its affections, and the laws of their recurrence.

But is the mind, as the materialist imagines, the result of a particular combination of material atoms? Do thought and feeling flow from a change in organized structure, as music from the vibration of a string? Or is their subject something, which is essentially independent of, and may survive the dissolution of the corporeal frame?

Our knowledge upon this matter is contained in a small compass. In the first place, we can imagine that mind may exist without matter; there is no contradiction involved in supposing each material element of our frame destroyed, yet the distinct recollection of all we have done and suffered and enjoyed remaining. 2. It is utterly impossible for us to conceive how matter can produce mental phenomena. 3. We are in possession of the fact, that while our bodily organs to a certain extent at least change, our mental identity remains. It is difficult to avoid concluding from these premises, that the human mind is something superadded upon and temporarily united to our living bodies, not a series of affections resulting from their material structure.

I shall conclude the present chapter with describing what is known of the condition of the mind during sleep, when the succession of the phenomena of consciousness often appears to be completely interrupted, and with a notice of a few of the more remarkable instances in which the ordinary course of the mental affections is disturbed.

Of Sleep.—The period of a diurnal revolution is shared between sleeping and waking: during six or eight hours of the twenty-four, consciousness appears suspended. After a day spent in active exercise, the limbs feel fatigued, the mind is less lively and less capable of continued attention, the senses become duller, we seek to dispose the body in a posture requiring the least muscular effort to sustain it, we withdraw the mind from reflections calculated to excite its powers, we seek to close the avenues of sensation, the images before the mind become more and more faint, and by insensible gradations we become unconscious.

During sleep the circulation is more gentle, the respirations are less frequent and are deeper, the temperature is lowered, the cutaneous transpiration is increased. The sleeper perhaps remains for several hours without motion, undisturbed by the loudest sounds or the brightest light.

If a sleeping person is awakened by another opening his eyelids under a strong light, the pupil for the first second or two is seen to be extraordinarily contracted, which we may presume to be its usual state during sleep: the pupil then becomes widely dilated, but again contracts and dilates before it becomes steady: at the same time the person moves himself, articulates unconnectedly, and seems endeavouring to collect his scattered thoughts. The mind quickly recovers its wonted character, the memory of the events of the preceding day returns, but with it in most cases no recollection presents itself of a state of consciousness between the period of falling asleep and that of waking.

Among the instances in which the memory affords no evidence of the existence of consciousness during sleep, some are nevertheless attended with phenomena, which distinctly show that consciousness has not been entirely suspended: for, that I may not mention breathing as an evidence of the persistence of volition (it being no doubt disputable whether each act of inspiration be voluntary or proceed from an automatic influence), a person asleep will sometimes turn his head from the light, or shift the position of a limb or of the body when it is reasonable to suppose that it has become inconvenient: and many animals sleep in postures in which they could not be sustained without the measured employment of voluntary muscles. Among many other facts of common observation, none perhaps is more conclusive than the estimate which seems to be made of the flight of time during sleep, so that a person anxiously bent upon awaking for an important object at a definite hour, will be sure, against his usual habits, and in defiance even of accidental fatigue, to wake before the hour required. The mind must have been to a certain degree observant during that sleep, which is so timely shaken off.

There are other instances in which the memory retains the clearest impression of various affections of consciousness having taken place during sleep. In dreams, the images presented to the mind are sometimes incoherent and disjointed fragments of events: at other times the train of imaginary circumstances is connected, and capable of producing an interest as intense as reality. Sometimes the mind is in its finest mood of invention. The musician and the poet have been known to regret, upon waking, their imperfect remembrance of what seemed the brightest gems of their fancy. Sometimes a dream is but the

imaginary continuation of trifling or important engagements of the preceding day; at other times it shapes itself to the present impressions upon the senses, and a sound imperfectly heard, a light flashing upon the closed eyelids, suggests to the imagination a rapid train of correspondent images, of which it forms a part. At the moment of waking, dreams are often freshly remembered, which quickly fade from the recollection: at other times some accidental association brings distinctly before us the events of a dream, which till that moment had never been recollected; leaving it uncertain how frequently the mind may thus energize, though its impressions associated with no object of sense may often fail of being brought back to the mind in its waking state.

The train of thought in ordinary dreaming is the spontaneous produce of our imagination, freed from the restraint which the perception of surrounding objects imposes upon us when awake. The character of an individual might therefore be elucidated by a history of his dreams; nor is it more wonderful that their suggestions should sometimes be prophetic, than that a rational judgment should frequently be able to foresee the probable occurrence of events, or that in the varied combinations of hazard a wild suggestion of the waking fancy should sometimes be realized. It is singular that a dream seldom has any reference to recent events, unless they have been such as to interest the mind in the strongest degree; and then it commonly happens that the supposed events in the dream are the opposites of the reality which has suggested them. Captain Back told me, that in his expedition with Captain Franklin, when nearly starved, he dreamed nightly of partaking of hearty meals.

But dreams are not always the passive flow of fancy; occasionally the mind seems to bend itself during a dream to an examination of the impressions which occupy it. It must have happened, for instance, to every one during a dream to have suspected that he was dreaming, and after a process of deliberate reflection to have become satisfied that he was awake.

It was the opinion of Dugald Stewart, that in sleep "the will loses its influence over those faculties of the mind, and those members of the body, which during our waking hours are subjected to its authority*." In the remarks which I have

* Stewart's Philosophy of the Human Mind, vol. i, p. 330.

made upon the phenomena of consciousness, I have employed the term will to signify exclusively that affection of the mind, which is the immediate cause of muscular action: that *this* influence is not in every case suspended during sleep, appears evident from the fact already adverted to, that many animals sleep in postures which require a sustained muscular effort. But we seem to exercise a voluntary power likewise over the affections of the mind: let us examine, before resuming the preceding inquiry, whether the latter influence be suspended during sleep. The faculty by which we direct the mind at pleasure to one train or mode of thought or to another, is essentially unlike that by which we produce a series of voluntary movements. Under ordinary circumstances we are indeed equally led to either,—to analyse for instance an affection of consciousness, or to strip the shell from a filbert,—by the gratification it promises: but while in the one case the effect we desire is attained directly and instantaneously,—we will and the muscles act,—in the former the effort consists in fixing the attention upon a subject of inquiry, and patiently observing the bearing of every thought which presents itself upon the point before us. In producing a muscular effort, we will a physical change, and it instantly ensues; in an effort of thought, we but confine the mind to a definite track, expecting that our established habits of association will bring us to the conclusion we wish.

Now it appears from an instance of dreaming already mentioned, that the mind can during sleep set on foot an analytical inquiry, and may compare its different impressions in order to arrive at a conclusion respecting their nature,—an operation as voluntary, if the expression be applicable, as any which the mind exhibits in its waking state.

Mr. Stewart supposes that the phenomena of nightmare or incubus illustrate the suspension of the influence of the will during sleep. The patient appears to himself to experience uneasy sensations, produced perhaps in part by the accidental posture of his body, which he finds it impossible to remove by his own efforts, and he feels distinctly conscious of an incapacity to move: or in a case perfectly analogous he imagines himself pursued during a painful dream, and attempts to fly, and his legs seem to refuse to perform their office. But it appears questionable whether in these instances the supposed effort of the will really takes place. The person is not conscious

of his real position (if he were he would be awake), and makes no effort to change *that.* He may possibly be suffering an uneasy sensation, but it is not presented in its true form to the mind; it is wrought up in all the horrors of a dream, and the attempts to escape from the load are in their nature fictions as well as the sufferings which suggest them. A person wide-awake will occasionally give the reins to his fancy, and frame before his mind scenes of the most exciting description, in which he supposes himself to play a busy part, interfering, perhaps, to save by an exertion of strength and activity, or indulging in the happiest flow of eloquence, in keen and pointed reply to imaginary invective, the very tone of which is supposed to add to its poignancy; but not a muscle does he move, although the scene in which he is engaged has an interest almost equal with reality. In a troublesome dream the case is similar; but the patient is essentially lost to every thing external, and having no means of detecting their unreal nature, is wholly absorbed in the creations of his fancy, to which alone his anxiety and his fears have reference. He wishes not to jump out of bed, but to escape the grinning jaws of the monster that threatens him. He is uneasy and oppressed, but there is no real load to be thrown off.

Perhaps therefore it is more just to say that the influence of the will over the voluntary muscles during sleep, instead of being suspended, *appears nót to be habitually exerted;* unless indeed breathing is voluntary. But there are some persons who talk during their sleep, as absent persons sometimes indulge themselves in making remarks aloud, or in gestures which have reference to the reverie in which they are engaged. The phenomena of somnambulism likewise, although very imperfectly understood, concur with the preceding instance in distinctly proving the exertion and influence of the will during a modification of sleep. In many cases of this affection it appears that the main action conducted has reference to a dream, while the somnambulist, though little conscious of surrounding objects, yet appears in part to be guided by sensation in his voluntary efforts.

A fit of somnambulism, observes Dr. Prichard, is in fact a dream so modified that the dreamer gains the power of pursuing, by voluntary motion, the objects which he is desirous of seeking or avoiding in his reverie. This near relation of the state of somnambulism to that of ordinary dreaming is proved by

the fact, that sleepwalkers, after they have awakened from the slumbers, which ushered in the fit of somnambulism, have sometimes remembered their adventures and have correctly related them: not however as transactions in which they had been actually engaged, but merely as the impressions of their dreams*.

To exemplify the phenomena of somnambulism, I borrow a narrative from Dr. Abercrombie's work on the intellectual powers.

"I have received," says Dr. Abercrombie, "from an eminent medical gentleman in London, a case presenting some interesting features, which occurred in the person of a young man residing in his house as a pupil. This young gentleman was a zealous botanist, and had lately received the highest botanical prize from a public institution. One night, about an hour after he had gone to bed after his return from a long botanical excursion, his master, who was sitting in a room below, heard a person coming down stairs with a heavy measured step, and on going into the passage found his pupil with nothing on him but his hat and his shirt, his tin case swung across his shoulders, and a large stick in his hand. His eyes, says the narrator of the case, were more open than natural, but I observed he never directed them to me, or to the candle which I held. While I was considering the best method of getting him to bed again, he commenced the following dialogue. 'Are you going to Greenwich, sir?' 'Yes, sir.' 'Going by water, sir?' 'Yes, sir.' 'May I go with you, sir?' 'Yes, sir: but I am going directly, therefore please to follow me.' Upon this I walked up to his room, and he followed me without the least error in stepping up the stairs. At the side of his bed, I begged he would get into the boat, as I must be off immediately. I then removed the tin case from his shoulders, his hat dropped off, and he got into bed, observing he knew my face very well,—he had often seen me at the river side. A long conversation then ensued between him and the supposed boatman, in which he understood all that was said to him, and answered quite correctly respecting botanical excursions to Greenwich made by the Professor of botany and his pupils; and named a rare plant he had lately found, of which the superintendant of the botanical garden had seen only one specimen in his life, and the Professor only two. After some further conversation, he was

* Prichard on Diseases of the Nervous System, p. 400.

asked whether he knew who had gained the highest botanical prize, when he named a gentleman, but did not name himself. 'Indeed!' was the reply: 'did he gain the highest prize?' to this he made no answer. He was then asked, 'Do you know a Mr. ——,' naming himself; after much hesitation, he replied, 'If I must confess it, my name is ——.' This conversation lasted three quarters of an hour, during which time, he never made an irrelevant answer, and never hesitated, except about the prize and his own name. He then lay down in bed, saying he felt tired, and would lie upon the grass till the Professor came. But he soon sat up again, and held a long conversation with another gentleman who then came into the room, when he again understood every thing that was said to him, and answered readily and correctly, sometimes uttering long sentences without the least hesitation. After a conversation of about an hour, he said, 'It is very cold on this grass, but I am so tired I must lie down.' He soon after lay down, and remained quiet the rest of the night. Next morning he had not the least recollection of what had passed, and was not even aware of having dreamed of any thing."

The following instance, quoted by Dr. Abercrombie from the papers of the late Dr. Gregory, is curious from combining the phenomena of dreaming, produced by external impressions, with somnambulism. The subject of the narrative was an officer in the expedition to Louisbourg in 1758, who was known to be liable to be affected, if whispered to when asleep, by dreams, which took a colour from what was said to him. His companions in the transport in which they sailed were in the constant habit of amusing themselves at his expense. They could produce in him any kind of dream, by whispering into his ear, especially if this was done by a friend, with whose voice he was familiar. At one time they conducted him through the whole progress of a quarrel which ended in a duel; and when the parties were supposed to be met, a pistol was put into his hand, which he fired, and was awakened by the report. On another occasion they found him asleep upon the top of a locker in the cabin, when they made him believe he had fallen overboard, and exhorted him to save himself by swimming. He immediately imitated all the motions of swimming. They then told him that a shark was pursuing him, and entreated him to dive for his life. He instantly did so with such force as to throw himself entirely from the locker upon the cabin floor,

by which he was much bruised and awakened of course. After the landing of the army at Louisburgh, his friends found him one day asleep in his tent, and evidently much annoyed by the cannonading. They then made him believe that he was engaged, when he expressed great fear, and showed an evident disposition to run away. Against this they remonstrated, but at the same time increased his fears by imitating the groans of the wounded and the dying; and when he asked, as he often did, who was down, they named his particular friends. At last they told him that the man next himself in the line had fallen, when he instantly sprung from his bed, rushed out of the tent, and was roused from his danger and his dream together by falling over the tent ropes. A remarkable circumstance in this case was, that after these experiments he had no distinct recollection of his dreams, but only a confused feeling of oppression or fatigue, and used to tell his friends that he was sure they had been playing some trick upon him.

The most remarkable cases, however, of somnambulism are those, in which there is no interval of ordinary sleep; the patient rushing at once from one state to the other, and existing, as it would appear, in alternating states of consciousness, in both of which external impressions are perceived, but those of one period never remembered in the other. The following striking instance was communicated to me by Dr. G. Barlow.

"This young lady has two distinct states of existence; during the time that the fit is on her, which varies from a few hours to three days, she is occasionally merry and in spirits, occasionally she appears in pain, and rolls about in uneasiness; but in general she *seems* so much herself that a stranger coming into the room would not remark any thing extraordinary. She amuses herself with reading or working, sometimes plays on the piano *better* than at other times, knows every body, and converses rationally, and makes very accurate observations on what she has seen and read. The fit leaves her suddenly, and she then forgets *every thing* that has passed during it, and imagines that she has been asleep, and sometimes that she has dreamt of any circumstance that has made a vivid impression on her. During one of these fits she was reading one of Miss Edgeworth's Tales, and had in the morning been reading one of them to her mother; she went for a few minutes to the window, and suddenly exclaimed, 'Mamma, I am quite well, my

headach is gone;' returning to the table she took up the open volume which she had been reading five minutes before, and said, 'What book is this?' she turned over the leaves, looked at the frontispiece, and replaced it on the table; seven or eight hours after, when the fit returned, she asked for the book, went on at the very paragraph where she had left off, and remembered every circumstance of the narrative; and so it is always, as she reads one set of books during one state and another during the other. She seems to be conscious of her state, for she said one day, 'Mamma, this is a novel, but I may safely read it: it will not hurt my morals, for when I am well I shall not remember a word of it.'"

b. Spectral Illusions.—In somnambulism and its varieties, sensations are perceived and acted on during dreams. Spectral illusions are the reverse of this. The subject of them is wide awake; but with his real sensations, strong and vivid conceptions of absent persons, or things, mix themselves, which are not distinguishable from his perceptions except by a strong effort of reflection and comparison of the one with the other. To illustrate this subject, I will first quote the account given by Nicolai, a bookseller in Berlin, of his own remarkable case.

"During the ten latter months of the year 1790, I had experienced several melancholy incidents, which deeply affected me, particularly in September, from which time I suffered an almost uninterrupted series of misfortunes, that afflicted me with the most poignant grief. I was accustomed to be bled twice a year, and this had been done once on the 9th of July, but was omitted to be repeated at the end of the year 1790. I had in 1783 been suddenly taken with a violent vertigo, which my physicians imputed to obstructions in the fixed vessels of the abdomen, brought on by a sedentary life, and a continual exertion of the mind. This indisposition was successfully removed by means of a more strict diet. In the beginning I had found the use of leeches applied to the arms particularly efficacious, and they were afterwards repeated two or three times annually, when I felt congestions in the head. The last leeches which had been put on previous to the appearance of the phantasms of which I am about to speak, had been applied on the 1st of March, 1790; less blood had consequently been evacuated in 1790 than was usual with me, and from September I was constantly occupied in business that required the most

unremitted exertions, and which was rendered still more perplexing by frequent interruptions.

"I had in January and February of the year 1791 the additional misfortune to experience several extremely unpleasant circumstances, which was followed on the 24th of February by a most violent altercation. My wife and another person came into my apartment in the morning in order to console me; but I was too much agitated by a series of incidents, which had most powerfully affected my moral feeling, to be capable of attending to them. On a sudden I perceived, at about the distance of ten steps, a form like that of a deceased person. I pointed at it, asking my wife if she did not see it? It was but natural that she should not see any thing; my question therefore alarmed her very much, and she sent immediately for a physician. The phantasm continued about eight minutes. I grew at length more calm, and being extremely exhausted, fell into a restless sleep, which lasted about half-an-hour. The physician ascribed the apparition to violent mental emotion, and hoped there would be no return; but the violent agitation of my mind had in some way disordered my nerves, and produced further consequences, which deserve a more minute description.

"At four in the afternoon the form which I had seen in the morning re-appeared. I was by myself when this happened, and being rather uneasy at the incident, went to my wife's apartment, but there likewise I was prevented by the apparition, which, however, at intervals disappeared, and always presented itself in a standing posture. About six o'clock there appeared also several walking figures, which had no connection with the first.

"After the first day the form of the deceased person no more appeared, but its place was supplied with many other phantasms, sometimes representing acquaintances, but mostly strangers: those whom I knew were composed of living and deceased persons, but the number of the latter was comparatively small. I observed the persons with whom I daily conversed did not appear as phantasms, these representing chiefly persons who lived at some distance from me.

"These phantasms seemed equally clear and distinct at all times, and under all circumstances, both when I was by myself and when I was in company, and as well in the day as at

night, and in my own house as well as abroad ; they were however less frequent when I was in the house of a friend, and rarely appeared to me in the street. When I shut my eyes those phantasms would sometimes vanish entirely, though there were instances when I beheld them with my eyes closed ; yet when they disappeared on such occasions, they generally returned when I opened my eyes. I conversed sometimes with my physician and my wife of the phantasms which at the moment surrounded me ; they appeared more frequently walking than at rest, nor were they constantly present. They frequently did not come for some time, but always reappeared for a longer or shorter period, either singly or in company, the latter, however, being most frequently the case. I generally saw human forms of both sexes, but they usually seemed not to take the smallest notice of each other, moving as in a market-place, where all are eager to pass through the crowd ; at times, however, they seemed to be transacting business with each other. I saw also several times people on horseback, dogs, and birds. All these phantasms appeared to me in their natural size, and as distinct as if alive, exhibiting different shades of carnation in the uncovered parts, as well as different colours and fashions in their dresses, though the colours seemed somewhat paler than in real nature ; none of the figures appeared particularly terrible, comical, or disgusting, most of them being of an indifferent shape, and some presenting a pleasing aspect. The longer these phantoms continued to visit me, the more frequently did they return, while at the same time they increased in number about four weeks after they had first appeared. I also began to hear them talk ; the phantoms sometimes conversed among themselves, but more frequently addressed their discourse to me ; their speeches were commonly short, and never of an unpleasant turn. At different times there appeared to me both dear and sensible friends of both sexes, whose addresses tended to appease my grief, which had not yet wholly subsided ; their consolatory speeches were in general addressed to me when I was alone. Sometimes, however, I was accosted by these consoling friends while I was engaged in company, and not unfrequently while real persons were speaking to me. These consolatory addresses consisted sometimes of abrupt phrases, and at other times they were regularly executed.

"Though my mind and body were in a tolerable state of sanity all this time, and these phantasms became so familiar to me that they did not cause me the slightest uneasiness, and though I even sometimes amused myself with surveying them, and spoke jocularly of them to my physician and my wife, I yet did not neglect to use proper medicines, especially when they began to haunt me the whole day, and even at night as soon as I waked.

"At last it was agreed that leeches should be again applied to me as formerly, which was actually done April 20th, 1791, at eleven o'clock in the morning. No person was with me besides the surgeon; but during the operation my chamber was crowded with human phantasms of all descriptions. This continued uninterruptedly till about half-an-hour after four o'clock, just when my digestion commenced. I then perceived that they began to move more slowly. Soon after their colour began to fade, and at seven o'clock they were entirely white. But they moved very little, though the forms were as distinct as before; growing, however, by degrees, more obscure, yet not fewer in number, as had generally been the case. The phantoms did not withdraw, nor did they vanish, a circumstance which previous to that time had frequently happened. They now seemed to dissolve in the air, while fragments of some of them continued visible for a considerable time. About eight o'clock the room was entirely cleared of my fantastic visitors.

"Since that time I have felt twice or three times a sensation as if these phantasms were going to reappear, without, however, actually seeing any thing. The same sensation surprised me just before I drew up this account, while I was examining some papers relative to these apparitions, which I had drawn up in the year 1791."

A gentleman, whom I have the pleasure of knowing intimately, and than whom no one enjoys a saner or better regulated mind, joined to habits of temperance amounting to abstemiousness, gave me the following narrative of a strong mental delusion, which had occurred to himself.

"In the autumn of 1816 I crossed the Black Sea from Odessa to Constantinople. This morning (October 20, 1831), while writing a letter on business respecting directions from

the Board of Health for precautionary measures against the cholera, my attention was suddenly diverted from the subject before me, and irresistibly fixed upon the vision or representation of a scene that occurred on my arrival at Constantinople in 1816. So strong was the impression, that all appeared actually present as it had been near sixteen years before. I had accompanied the captain of a vessel, a Frenchman, to visit a friend of his long established in the French palace as head gardener. I followed him to the apartment of Mr. M—— (so he was called, as I recollected this morning), situated in the basement story of the palace, and opening into the garden. This was the scene I saw to-day. The captain and the old man standing in the middle of the floor; the old woman, his wife, opening a cupboard door, where bottles, glasses, and other articles appeared. One daughter spreading a white cloth upon a small table; the other daughter seated near the window looking into the garden: she was working on a quantity of white muslin, or fine linen, which rested in a basket at her side: her feet were raised upon a low wooden bench. The captain complimented her on her improved appearance, and announced to me her great proficiency in various languages. The father added that she could write as well as speak them, thanks to the kindness of Madame the embassadress, now returned to France, an irreparable loss to him and his family. The variety of attitude of the persons, the sounds of their voices, the rays of light falling on the objects in the interior through the door and window, and partially illuminating the figures as they crossed the bright track; the garden with flowers in the full sunshine near the door, and the chequered shadow of the waving trees upon one part, in short the whole scene,—appeared for a short time distinctly visible, I have no doubt exactly as it really occurred at the time referred to. The plague had just broken out, and was the subject of much inquiry to new arrivals at Constantinople. The gardener said his family now scarcely ever left the palace. Perhaps the similarity of reflection and inquiry respecting the cholera may have induced the vivid recollection of this trivial occurrence. The vision apparently lasted some minutes. At first my attention was entirely engrossed by it. I then became alarmed by its occurring to me that such a delusion must be the effect of

fever; on rising to ring the bell, the whole vision gradually became faint and disappeared. I immediately wrote these notes of the circumstance."

Dr. Abercrombie mentions the case of a gentleman, who has been all his life affected by the appearance of spectral figures. To such an extent does this peculiarity exist, that if he meets a friend in the street, he cannot at first satisfy himself whether he really sees the individual or a spectral figure. By close attention he can remark a difference between them, in the outline of the real figure being more distinctly defined than that of the spectral; but in general, he takes means for correcting his visual impression by touching the figure, or by listening to the sound of his footsteps. He has also the power of calling up spectral figures at his will, by directing his attention steadily to the conception of his own mind; and this may either consist of a figure or a scene, which he has seen; or it may be a composition created by his imagination. But though he has the faculty of producing the illusion, he has no power of banishing it; and when he has called up any particular spectral figure or scene, he never can say how long it may continue to haunt him. The gentleman is in the prime of life, of sound mind, in good health, and engaged in business. Another of his family has been affected in the same manner, though in a slighter degree.

c. Of Mental Failure and Decay.—It has been remarked, that of the powers of the mind, the memory is the first to decay. Old age, which impairs the mind, makes its first inroad on the memory. Wine, while it raises the animal spirits and stimulates the fancy, at the same time disturbs the memory. After injuries of the head, that have eventually been followed by idiotcy, the failure of the memory has been the first mental symptom observed.

The failure of memory is perhaps sometimes considered the only impairment of the mind, when in fact its other powers are likewise injured: inasmuch as an alteration is much more readily detected in the memory than in any other faculty. It is possible likewise, that in many instances it is more properly the recollection than the memory which suffers; the remembrance is not lost, but the facility of finding it in the mind: so that the change would be more justly stated to be in an impairment of the liveliness and rapidity of association. I

have heard it observed of old men, that their memory has become impaired, but that their understanding has remained as strong as formerly, only slower in its operations. A supervening slowness of association or mental suggestion would account in these instances for all the phenomena observed.

How much we may remember, which we cannot recollect, is shown by a curious class of cases, several of which have been collected by Dr. Prichard, in his work upon the nervous system, from which I extract the following.

"A man was brought into St. Thomas's Hospital, who had received a considerable injury of the head, but from which he ultimately recovered. When he became convalescent, he spoke a language which no one about him could comprehend. However, a Welsh milkwoman came one day into the ward, and immediately understood what he said. It appeared that the patient was a Welshman, and had been absent from his native country about thirty years. In the course of that period he had entirely forgotten his native tongue, and acquired the English language. But when he recovered from his accident, he forgot the language he had been so recently in the habit of speaking, and regained the knowledge of that which he had originally acquired and lost*."

"A student at an university in the United States, who is now one of the most respectable clergymen in that country, possessed a tolerable share of classical knowledge, when the consequences of a fever, which affected his brain, deprived him entirely of his former acquisitions. In fact, he had now become so ignorant, that he was not only unable to read a Latin book, but even knew nothing of the grammar. When he had regained his bodily health, being of a persevering disposition, he began again the first rudiments: every thing was quite new to him: he passed through the accidence and syntax in his grammar, and was learning to construe, when one day, as he was making a strong effort to recollect a part of his daily lesson, the whole assemblage of the ideas which he had formerly acquired and lost, suddenly reappeared to his mind, and he found himself able to read and understand the Latin authors as he had done before his illness."

* Dr. Tupper's Inquiry into Gall's System of Craniology.

SECTION II.

Of the Elements of a Nervous System.

The hydra viridis, upon which the first experiments of Trembley were made that showed the divisibility of the lower animals without loss of life in either half, is a thin gelatinous tube about an inch in length, closed at its narrower end. The open extremity is bordered by a fringe of long and slender filaments or tentacula. By means of these the polyp distinguishes and seizes its prey, and conveys it into its digestive cavity. It moves from place to place by alternately attaching either extremity to intermediate points. Its structure seems a coherent jelly containing innumerable granules. When the animal is turned inside out, the new internal surface is capable of digesting: when divided, each half becomes a perfect polyp.

Thus in the lowest animals the vital endowments are generally and equally diffused through their whole frame: each half of a polyp may form a portion of one and the same sentient being, or become upon mechanical division individualized.

Cuvier arranged all the families of animals under four classes, which consist, 1, of radiated; 2, of articulated animals; 3, of mollusca; 4, of vertebral animals. The polyp is nearly at the commencement of this series; but in the same division other animals are found, which have a distinction of organs, and a nervous system.

As soon as a nervous system is discernible, the phenomena of consciousness are found to be centered in it; or it forms henceforth their exclusive organ.

The material of which a nervous system is formed, is a soft viscid tenacious substance, varying in colour from an orange white to brown, from a bright yellow to grey or black. When a thin slice of nervous matter is smeared upon glass, and viewed in a microscope under a drop of water, it appears to consist of an aggregation of minute molecules of different sizes, the largest considerably smaller than a particle of the blood.

Nervous substance is generally shaped into rounded masses,

or into cylindrical or flattened cords. These are invested with membrane, which covers not merely their superficies, but penetrates their whole substance, giving it a determinable structure. The common type of this structure, as far as regards the nervous matter, is fibrous, and as regards the membranous investments, tubular. Or, the viscid doughy material peculiar to the nervous system is deposited in a series of fine membranous tubes. The consistence of the nervous matter in different parts of the system varies. The difference depends upon the quantity and thickness of the membrane in each part; and that again depends upon the degree to which the part is exposed to mechanical strains or violence.

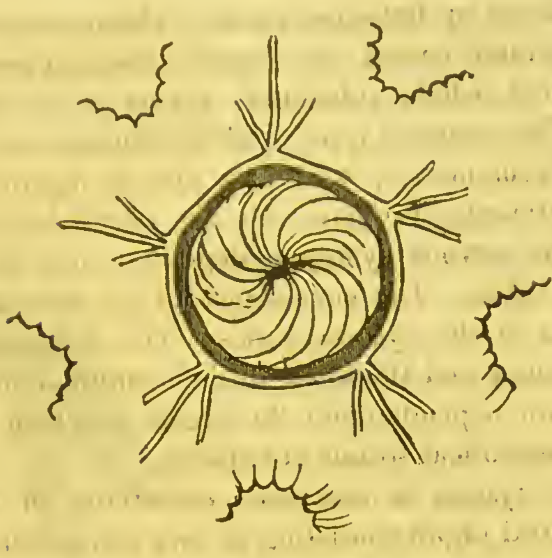
A nervous system is composed essentially of two parts; first, of a central organ consisting of two cords, united at their extremities, one corresponding with either lateral half of the body, upon which nodular masses are generally placed; secondly, of other cords called nerves, derived from the central organ to the sentient surfaces or contractile parts of the animal.

The two cords which form the central organ of the nervous system may be disposed either in parallel lines, and touch each other for their whole extent; or each may describe an irregular line, and the two may enclose a space.

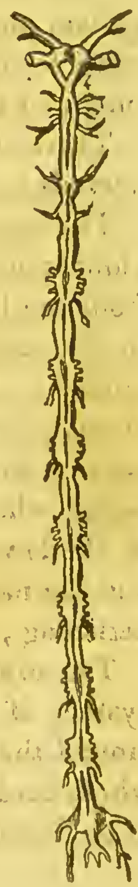
There are three types in the animal kingdom after which the nervous system is framed.

The first is adapted to classes of animals, some of the individuals of which survive in each half mechanical division, and from one become two sentient beings. This type is followed in the nervous systems both of radiated and of articulated animals. Individuals of the lowest species, in both of these classes, consist of several segments arranged either around a centre, whence the term radiated, or in a successive jointed series, whence the term articulated, is derived. There are many of the lowest species in either class, the star-fish for example, and the nais, which admit of being divided without either part perishing; each half becomes a perfect animal.

The adjoined figure from Tiedemann represents the nervous system of a star-fish. The central organ is a cord disposed around the orifice of the alimentary cavity, from the points of which cord, that are opposite to each ray, nerves are given off to be distributed to it.



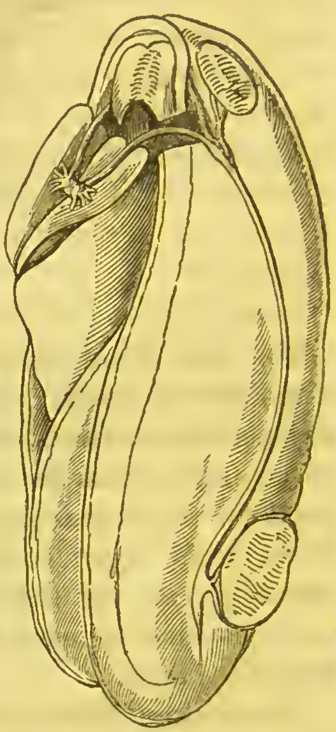
The next figure, intended to typify the nervous system of articulated animals, represents the nervous system of the scolopendra morsitans, copied (with the omission of several of its central nodules to shorten the figure) from Mr. Newport's paper in the Philosophical Transactions for 1834. The central organ consists of a double cord disposed in two parallel lines, with a nodule upon each, in each segment of the animal, from which the nerves arise.



The distinguishing character of the double cord in the scolopendra, as representing articulated animals, is not, however, its disposition in two parallel lines. This circumstance has reference to the external figure alone of the animal, as is proved by comparing the anatomy of the lobster with that of the crab. In the former, the central organ of the nervous system, in its general disposition, resembles that of the scolopendra; in the latter it is thrown into a circle. The essential distinction between the central organ in the scolopendra and that in the star-fish, is the nodular enlargements in the former at the points where nerves originate.

The common point between the two, which brings them to the lowest or composite type of organization, is the equal development of the nervous cord at every part of the animal, no segment showing a remarkable superiority of volume over the rest.

To this peculiarity of structure is doubtless attributable the fact, that sensibility is not destroyed in the tail of some animals of this construction, when the hinder part of the body is cut off, any more than in a segment of a radiated animal separated from the rest.



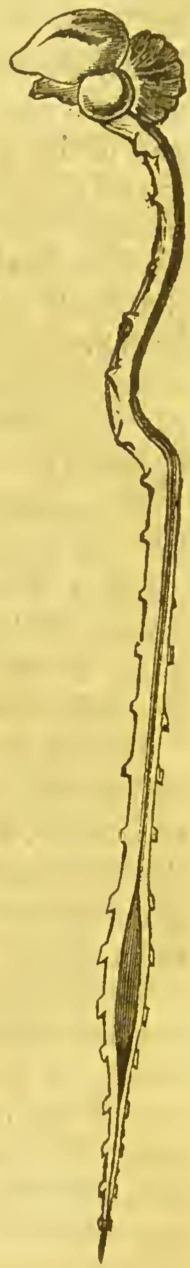
The second type is that which is met with in mollusca. The figure which I have given is from a preparation of the nervous system of a fresh-water muscle, made by Mr. Cæsar Hawkins.

Mollusca differ from animals of the two preceding classes in being essentially individualized. They each consist of a single series of organs, the co-operation of which is essential to the support of life. The internal organs not being repeated, but forming one system, evince a higher type of organization.

The nervous system of mollusca differs from that of the preceding classes in two respects. In the first place the nodules of the central organ are of disproportionate size, so that the connecting cord appears insignificant; nevertheless the connecting cord is invariably found to exist, uniting all the nodules into a continuous chain. In the second place, the nodules, although generally situated near to the organs which they supply, are found in greatest number and volume near what must be called the head, so as to form something like a brain. Nevertheless, the nodules which are remote from the head, may be presumed to be of equal force and function to those in the head: in structure at least they are exactly like the latter. In the fresh-water muscle it happens that the nodules in the head are of the brightest yellow colour, the connecting cord and the nerves being white: but the nodules in other parts of the body are equally characterized by this brilliant colour, which I presume is a sufficient proof that they are of the same nature with the first.

In the three lowest classes of animals, that is to say, in the

radiata, the articulata, and the mollusca, the disposition of the double cord has always a certain relation to the opening into the stomach. It is either wholly disposed in a circle round what must be termed the œsophagus, as in several radiated animals; or the part which extends between the first and second pair of nodules forms a collar through which the œsophagus passes, as in articulated animals and in mollusca.



In articulated animals, the first pair of nodules, like a brain, is placed above the mouth and commencement of the œsophagus, whilst the remainder are disposed upon the strong integument of the abdomen in the securest region of the frame.

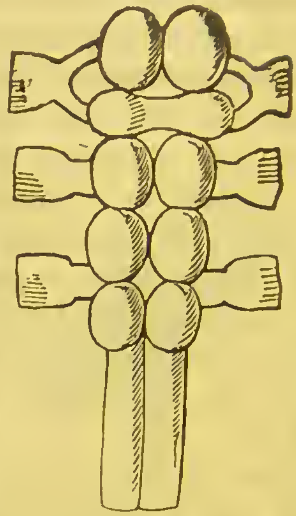
In the higher mollusca, in the snail for instance, and in the cuttle fish, the upper portion of the nervous centre, or the first pair of nodules, assumes more of the external character of a brain: still in both of these instances there is found below the œsophagus a second portion (analogous to the spinal marrow and medulla oblongata of the next class), to which the first is united by two cords, which complete the never-wanting œsophageal collar.

The third and highest type is that which reigns in vertebral animals: the figure which I have given as an example of this type, represents the central organs of the nervous system in the pigeon.

In vertebral animals, the central organ consists of a double cord, the greater part of which is contained in the vertebral canal, and is called the spinal cord, or spinal marrow, while its upper or anterior extremity is prolonged into the cranial cavity, and is called the medulla oblongata. From this double cord, like as in the three preceding classes of animals, nerves are given off in pairs to the successive segments of the frame. So far therefore, parts very strictly parallel are found in vertebral animals and in the lower classes.

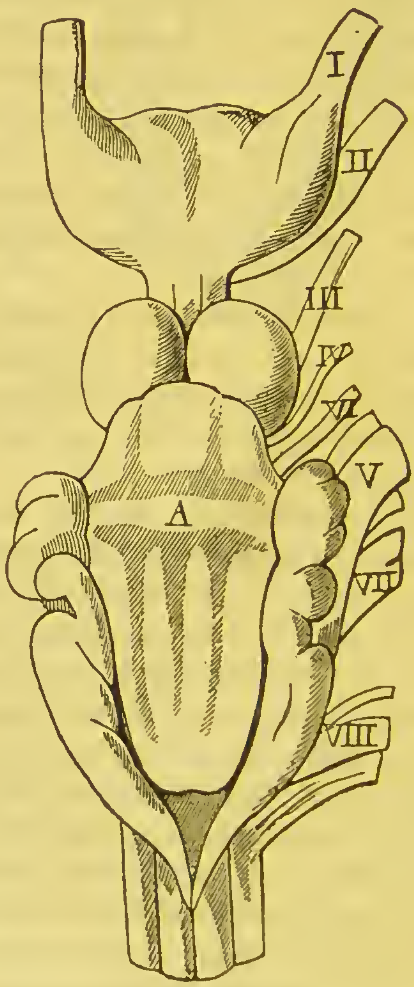
It is true that in the greater number of instances the spinal cord is not nodular, as in the articulated

animals and mollusca. Yet it is observed, that in most there are general swellings and enlargements of the cord at the parts whence the larger nerves, or those of the extremities, arise. Instances likewise are not entirely wanting in which the nodular construction distinctly shows itself. The figure adjoined represents the upper part of the spinal marrow of a gurnet (from the plates of Desmoulins and Magendie), in which *that* portion of the spinal cord, from which nerves of finer endowments, those namely which supply the feelers, are given off, is found to be nodular.



The cranial part of the double cord is, however, invariably crowned with hemispherical masses analogous to the nodules of the lower animals, from which nerves arise in pairs.

The adjoined figure of the enkephalon of a skait, seen from above, with (on one side) the representations of the origin of the nerves, may serve as an example.

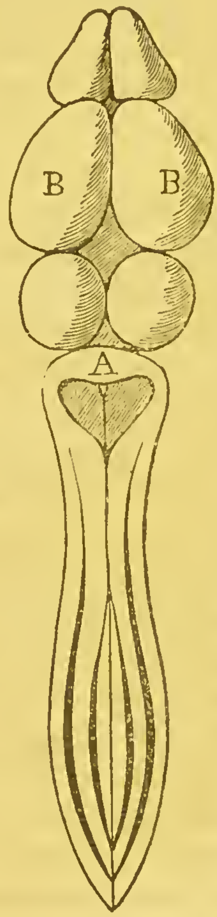


The accumulation of larger nodules in the head, upon the summit of the double cord, is one of the characteristic features of the nervous system in vertebral animals. But another remarkable point of distinction is never wanting; there are always found among

the nodules which give origin to the cerebral nerves, more than one other nodule, from which no nerves arise; of these in the skait the largest is the cerebellum, which in the diagram is marked with the letter A; the other parts of the same character are placed below; they are the pituitary gland, and the corpora albicantia.

In some fish, as for instance in the carp, other and additional tubercular masses not giving origin to nerves are found, which being placed anterior to the cerebellum, and like it having a superficies of grey matter, seem to constitute a cerebrum.

A cerebrum is always found in reptiles. The larger of the adjoined figures represents the enkephalon and spinal cord of a toad. The letters BB mark the two hemispheres of the cerebrum: the letter A is placed on the cerebellum, which is singularly small in ophidian and batrachian reptiles. The smaller figure represents the surface of a section of the cord in the toad.



The preceding details lead to three important conclusions respecting the functions of different parts of the nervous system in vertebral animals.

I. The higher animals are distinguished from the lower in the construction of their nervous system, by cerebral masses superadded upon the anterior end of the double cord. They are distinguished also by a larger share of mental endowments. Is it not probable that the superadded parts have to do with the superadded functions? Or, to proceed more cautiously in the argument,—both in the highest and in the lowest there are found a double cord with nerves arising from it, and there are displayed sensation, instinct, and volition: is it not likely, that in the highest animals sensation, instinct, and volition, have their material organs in the double cord and nerves, which with those functions are common to them and to the lowest?

One to whom the present inquiries are new may think this conjecture ingenious, but will certainly suppose it impossible to prove its correctness; nevertheless, nothing can be more complete than the body of evidence by which it is established.

It occasionally happens, that human fœtuses are born with a spinal cord, medulla oblongata, and nerves complete, but without a brain,—that is to say, deficient in the parts peculiar to vertebral animals, but having those which correspond with the entire nervous system of a star-fish, a centipede, or a snail. These brainless fœtuses commonly die in their birth: but they have been known to survive a few hours or days; and when this has happened, they have displayed sensation and instinct.

The following is an account by Mr. Lawrence of an acephalous infant, which lived four days.

"The brain and cranium of this infant were deficient, and the basis of the latter was covered by the common integuments, except over the foramen magnum, where there existed a soft tumour about equal in size to the end of the thumb. The smooth membrane covering this was connected at its circumference to the skin. The child, as is generally the case in such instances, was perfectly formed in all its other parts, and had attained its full size. It moved briskly at first, but remained quiet afterwards, except when the tumour was pressed, which occasioned general convulsions. *It breathed naturally,* and was not observed to be deficient in warmth until its powers declined. From a fear of alarming the mother no attempt was made to see whether it would take the breast: *a little food was given it by the hand.* It voided urine twice in the first day, and once a day afterwards. It had three dark-coloured evacuations. The medulla spinalis was found to be continued for about an inch above the foramen magnum, swelling out into a small bulb, which formed the soft tumour upon the basis of the skull. All the nerves from the fifth to the ninth were connected with this."

The conclusion deducible from this remarkable instance, that *in man the brain is not necessary for sensation and the commonest instinctive actions,* is further confirmed and illustrated by experiments made upon living animals.

M. Magendie mentions, that if after the removal of the upper part of the cranium in a living animal, the cerebrum, the optic tubercles, and the cerebellum are removed in successive slices,

leaving the medulla oblongata entire above the apparent origin of the fifth pair of nerves, the animal, although rendered blind, continues to be affected in as lively a manner by pungent odours or tastes, or by irritation of the skin, as if no further injury had been sustained than the loss of blood occasioned by the experiment. The animal cries, if a hair of its whisker is plucked, or if vinegar is held to the nose, and strives with its fore feet to rid itself of the object which incommodes it. The movements of the body are not more affected than if the cerebellum alone had been removed. These phenomena may be observed to continue for more than two hours, when the experiment is performed upon a full-grown hedgehog*.

II. The next step which we make discloses facts not less wonderful than the preceding.

It appears by the experiment, which I have last quoted, that the brain may be taken away portion by portion, yet the creature survive, and exhibit sensation and instinct. But let the mutilation be carried a line further; let that small segment of the medulla oblongata be destroyed, in which the fifth, seventh, and eighth nerves rise, and consciousness is instantaneously extinguished. Nor is this extraordinary phenomenon to be explained upon the supposition, that it is necessary for life that a certain *quantity* of the cerebral organ be left. It turns wholly upon the destruction of one particular segment: for in an animal in perfect health, and with all the frame entire, if that segment *alone* is cut through, life ceases at once.

And to mark yet higher the importance of this point in the medulla oblongata, the rest of the nervous system derives its vitality, or, to speak more justly, its participation in the phenomena of consciousness, from its continuity with this point being uninterrupted. This proposition, indeed, admits of proof, by experiments made upon cold-blooded animals alone. In warm-blooded animals, the functions of the nervous system depend so directly upon the circulation of the blood, that when the latter is interrupted, no satisfactory results can be obtained.

But in a frog or turtle, after the head has been severed from the body, consciousness persists for a time: and whether that principle of consciousness remain in the head or the body, depends entirely upon whether the section of the medulla oblongata has been made above or below the vital point which I have described. As a cook in killing a turtle generally divides

* Anat. des Syst. Nerv. &c. par F. Magendie et A. Desmoulins p. 560.

the medulla below the vital part, it is the body which is commonly found to be deprived of sensibility, while the separated head continues distinctly to exhibit consciousness. If it is contrived, however, that the section be made just above the origin of the fifth and eight nerves, an opposite result takes place — the head is dead, the body continues alive.

III. The preceding facts appear to establish an utter dissimilarity between the endowments of the nervous system, as it exists in vertebral, and in invertebral animals. That which can be divided, and either half retain its functions, is essentially unlike that, all the endowments of which depend upon the continuity of its different segments with one point. Nevertheless, although this important difference cannot be disputed, and it is certain in vertebral animals that all the parts of the nervous system, which are disconnected with a particular segment of the medulla oblongata, are excluded from participating in consciousness, still it is to be presumed, that as long as their continuity remains, each part exercises an energy of its own, or has its own function. And that, to begin with, each segment of the double cord from which a pair of nerves arises, has in itself a mechanism of sensation and instinctive action comparable to the parallel parts in articulate animals. The proof of this is contained in the following remarkable experiments made upon the body, a few seconds after it has been deprived of life. If the spinal cord is then divided in the middle of the neck and in the middle of the back, upon irritating a sentient organ connected with either isolated segment, muscular action is produced : if, for instance, the sole of the foot is pricked, the foot is suddenly retracted, with the same gesture as it would have been during life; that is to say, a sentient organ being excited, an irritation is thence propagated through the sentient nerve to the isolated segment of spinal marrow in which that nerve originates, where it gives rise to some change, which is followed by the transmission of an impulse along the voluntary nerves to the muscles of the part. That this is the true explanation of the phenomena observed, is conclusively shown by the following experiment, which it occurred to me to make when engaged in investigating the source of the motion of the iris. A pigeon being killed, and the head removed, the cerebrum, cerebellum, and medulla oblongata were separated from the optic tubercles and crura cerebri : all the nerves proceeding to the eye, with the exception of the third, were then divided ; and now the

stump of the optic nerve adhering to the optic tubercle was pricked, when I found that the iris acted. Thus, under the restrictions above laid down, each segment of the double cord, with the nerves derived from it, may be justly compared to a pair of nodules with its nerves in an invertebral animal.

We may therefore look at the nervous system as a chain of organs originating nerves in pairs, and make each segment, or group of segments with their nerves, a separate study; and consider in succession the spinal cord, the medulla oblongata, and the masses superimposed upon it. Or there is another point of view, under which we may consider the subject. Instead of contrasting one segment, or group of segments, with another, we may study the functions of the nerves as one system of organs, and those of the spinal cord and brain as another. It will be better in fact to adopt both of these modes of distributing the subject. The functions of the nerves will be therefore treated of apart: and in the mean time the functions of the spinal cord, of the medulla oblongata, and of the brain, will be described in succession.

SECTION III.

Of the Spinal Cord.

The spinal cord has to be viewed in several important relations. In the first place, being intermediate between the brain and the spinal nerves, it has the office of transmitting to and from the nerves and brain the impressions which travel from the one to the other.

Again, it has been shown by experiment, that in one part of the nervous system, in the nerves themselves namely, impressions are transmitted or propagated along or in the direction of the threads or filaments of which the nerves are formed. It is interesting to have ascertained [which I was enabled to do by employing the method which Reil had used in unravelling the structure of the brain], that the white matter of the spinal cord, like the nerves, is made up of longitudinal threads, part at least of which extend from the medulla oblongata to the termination of the cord. The effect, on this ground alone, of dividing the spinal cord theoretically ought to be, as it is practically found to be, analogous to the effect of dividing a nerve. The white fasciculi which form the spinal cord coalesce continually with each other by means of fine threads which pass obliquely from

one fasciculus to another. White threads likewise at intervals detach themselves from the cord, to contribute to the formation of the spinal nerves.

2. When we consider the spinal cord as consisting of threads which come from the enkephalon to communicate with the successive pairs of nerves, we conclude that after each pair the cord must be diminished in size; we expect to find the spinal marrow of a conical figure, tapering from the neck to the loins in proportion as it parts with nerves. And in fish, in which the body tapers, this is found to be strictly the case. In reptiles, birds, and mammalia, however, the figure of the cord is considerably modified, and a second principle in its construction is brought prominently into view. The cord consists, in truth, not only of threads extending from the enkephalon to the nerves, but likewise of a series of parts analogous to the nodules in the lower animals, which are concerned in originating nerves, and the size of which has reference to the size of the nerves given off at each part. Accordingly, although the spinal cord of reptiles, birds, and mammalia, tapers eventually to a fine extremity, yet is its narrowing twice interrupted by sensible enlargements, one of which is at the lower part of the neck, where the large nerves of the upper extremities arise, the other at the lower part of the back, where the nerves of the legs are given off.

3. How essentially independent these groups of originating organs are of each other is shown by the following remarkable case.

A person died at the age of forty-four, seven years after having lost the use of his arms, which had become contracted, without however losing their sensibility. The lower part of his body had in no degree participated in the same affection; and he had been to the last violently addicted to sexual indulgence. Upon dissection, the spinal cord at the lower part of the neck and upper part of the back, was found converted into a colourless diffluent substance containing flakes of nervous matter, all but two narrow bands, one in the line of each anterior lateral furrow, which appeared of their natural texture, and joined the sound inferior portion of the spinal cord to the upper part*. The narrow bands of a natural texture, described in this case, served to communicate the influence of the enkephalon to the lower segments of the spinal cord that were entire.

* Magendie, Journ. de Phys. Exper tome iv.

4. But the white filaments of the spinal cord serve not only to connect the brain and medulla oblongata with each segment of the cord, but to associate reciprocally the segments of which the cord itself consists. When the head of a snake has been cut off, the body is lifeless, and utterly deprived of sensibility. If, however, before many minutes have elapsed, the experiment is made of puncturing the skin of the tail or of the middle of the animal, the decapitated neck is seen to bend towards the point thus irritated. The several segments of the spinal cord still co-operate, and are capable of combining to excite habitual muscular actions, upon an impression being made upon the sentient nerves derived from one.

5. When the filamentous structure of the cord, the rationale of its shape, the independent elements that exist in it, and the possibility of the co-operation of the latter without the influence of the medulla oblongata, have thus been brought under review, it has further to be inquired, what are the longitudinal divisions of the cord, what is the disposition of the cineritious substance within the cord, what difference is there between the functions of the anterior and posterior fasciculi?

The spinal cord exhibits six well-marked longitudinal furrows upon its surface: two of these, called the anterior and posterior median furrows, mark its division into two symmetrical halves. Two lateral furrows on each half of the cord, near and parallel to the anterior and posterior median furrows, mark the lines at which the two roots of the spinal nerves are attached. Of all these furrows, the anterior median alone has a separable doubling of pia mater lining its whole depth. Through this circumstance in the recent state it is readily displayed. The posterior lateral furrows are the next in depth and coarseness. There are no furrows upon the sides of the spinal cord. But the furrow, which in the medulla oblongata intervenes between the posterior pyramid and corpus restiforme, is continued down two-thirds of the spinal cord between the posterior median and posterior lateral furrows.

I made the following measurements upon the spinal cord of a remarkably muscular body, the age of which was about twenty-five years, the height five feet four inches. Their principal physiological interest consists in their showing, that the depth of the anterior median furrow is greater at the inferior enlargement than at the cervical enlargement at the cord; that is to say, that the anterior portion of the spinal cord is relatively

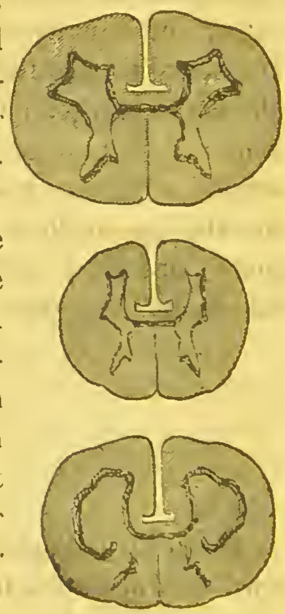
larger where the nerves of the lower extremities are given off, than at the part where the nerves of the upper extremities arise.

The entire length of the spinal cord, from the commencement of the decussation of the pyramids to its lumbar end, was 18.5. The fine remnant of nervous matter at the inferior end extended half an inch beyond the origin of the last nerve.

The measurements in the adjoined table are decimal parts of an inch.

Places of measurement.	Breadth of the entire cord.	Depth of the entire cord.	Depth of the anterior median furrow.
Dimensions of the spinal cord at the interval between the origins of the sixth and seventh cervical nerves	.57	.4	.15
Dimensions at four inches and a half above the origin of the last nervous filament..	.36	.34	.14
Dimensions at two inches above the last filament, or at the thickest part of the inferior enlargement.	.46	.38	.18

The disparity which is thus shown to exist in different regions between the anterior and posterior portions of the spinal cord becomes more remarkable, when the interior structure is displayed by transverse sections.



The three figures adjoined represent the surfaces of transverse sections at the three points of which measurements of the cord have been given. The upper figure corresponds with the cervical part [at the origin of the fifth cervical nerve], the middle with the dorsal; the lowest with the thickest part of the lumbar enlargement. The upper part of each figure represents the anterior surface of the cord.

These figures show the disposition of the grey matter in the interior of the spinal cord. The grey matter is not, as it is commonly supposed to be, a central solid pillar in either half; I discovered it to be a capsule only, analogous to the corpus

fimbriatum in the cerebellum, and containing white matter. The figure of the grey matter I discovered to be different and characteristic in the different portions of the cord. In the back, the figure of the grey matter is perhaps the most regular; in the inferior part alone does the anterior portion of the grey capsule, which is indeed elsewhere the larger of the two, acquire a strikingly disproportionate magnitude.

It is easy now to explain why the anterior portion of the spinal cord should be most developed at the *lower enlargement* of the cord. The conclusive experiments of Magendie, which terminated a long series of inquiries upon this subject, satisfactorily establish, that the anterior portion of the spinal cord has to do with voluntary motion exclusively, the posterior with sensation. But it is in the lower extremities that force of muscular action predominates over fineness of sensation, while in other parts of the body, and in the upper limbs, these two endowments may be viewed as nearly balanced. It is for this reason, without doubt, that that part of the cord which gives origin to the nerves of the lower extremities is characterized by the predominant bulk of its anterior portion, which is measurable both through the depth of the anterior median furrow and by the size of the anterior segment of the grey matter. For the supply of the trunk, where sensation and motion are moderately and equally developed, in which the motions are simple, the sensibility uniform, neither portion of the grey matter of the cord is large, neither predominant. The fineness of sensation and extent of motion of the upper extremities, as both exceed what are manifested in the trunk, so do they account for the approach to equality, joined with extent of development, observed in the anterior and posterior capsules of grey matter in the *upper enlargement* of the cord.

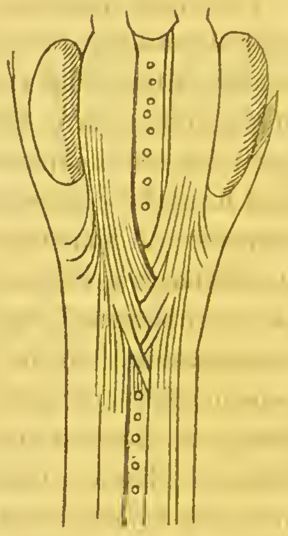
SECTION IV.

Of the Enkephalon.

The term enkephalon is given to the production of the double cord crowned with hemispherical masses, which is contained in the cranium. It comprehends the medulla oblongata, the cerebellum, the tubercles, the cerebrum. The lowest portion of the enkephalon, the immediate continuation of the spinal marrow,

is called the medulla oblongata: in the human brain, this part is a cone, 1.3 inches in length.

I. To accord with common usage, I here employ the medulla oblongata in a much more limited sense than it is analogically entitled to. Properly, it should comprehend the further production of the double cord to a point at which nerves cease to rise.



The adjoined figure represents the anterior and inferior surface of the medulla oblongata and its junction with the spinal marrow. The markings upon the former are different from those upon the latter. The disposition of the grey matter in the interior of the medulla oblongata is considerably more complicated than in the spinal marrow. The general character of structure, however, is the same in the medulla oblongata as in the spinal marrow: that is to say, the medulla oblongata consists externally of white matter, while within grey matter is disposed in thin layers, which alternate with the white, and have a remarkable tendency to form thin capsules containing white matter. After maceration in alkohol, the grey matter here, as in the cord, is found to be granular, the white matter fibrous.

The first question, which suggests itself, upon looking at this important organ, is the exact locality of the part which is the " link that binds us to life," or upon the lesion of which vitality is instantaneously extinguished. This part, judging from analogy, is situated about three lines below the inferior edge of the pons Varolii, the same distance of course from the summit of the medulla oblongata. It is situated therefore well within the skull, and securely lodged upon the basilar process of the occipital bone. When warm-blooded animals are destroyed by pithing, that is, by dividing the spinal marrow between the atlas and occiput, this vital part is not touched. Death is in this case produced, not as the direct consequence of the local lesion, but indirectly through suffocation. The spinal cord being cut through above the origin of the phrenic nerves, the animal cannot breathe: the blood is therefore no longer oxygenated in

passing through the lungs: and when the unchanged blood has circulated for a short time in the brain, stupor supervenes, and death. There is, however, an appreciable interval of half a minute, at least, during which the head of the animal sensibly retains consciousness. It is not improbable, that in decapitation by the guillotine, the head continues conscious for the period of a few seconds after its separation from the trunk.

The next question that occurs, regards the relation of the medulla oblongata to the nerves which rise from it. No doubt can be entertained that this relation is the same that obtains in the spinal cord: like the latter, the medulla oblongata is to a great extent comparable with the successive pairs of nodules that form the central organ of the nervous system in articulated animals. Accordingly we see the medulla oblongata, like the spinal marrow, varying in size with the nerves that arise from it. In fish, in general, the amplitude of the medulla oblongata is very considerable. In the common skait [see the figure at page 208] considerable processes of grey matter, of a remarkably elegant form, rise from the medulla oblongata at the sides of the cerebellum. Their relation to the origin of the fifth and eighth nerves is conclusively established by comparing the enkephalon of the skait with that of the torpedo. In the latter the fifth and eighth nerves are of prodigious size, having to supply the electric organs; and the masses of grey matter on the upper aspect of the medulla oblongata enclosing the cerebellum are proportionately large and voluminous. It may not be uninteresting to remark in addition, that in the enkephalon of the torpedo the cerebellum, which is flanked by these masses of grey matter, is itself rather smaller than in the skait.

A third question is the office of the medulla oblongata as a transmitting organ.

All that is received of the ministration of the medulla oblongata to this office during health is deduced from its anatomical structure, respecting which three propositions may be laid down.

a. The greater part of each half of the medulla oblongata, that is to say, all but the corpus restiforme and the anterior pyramid, is continuous with a tract, which ascends behind the pons Varolii to the cerebral hemisphere of the same side; and therefore places that cerebral hemisphere in mechanical

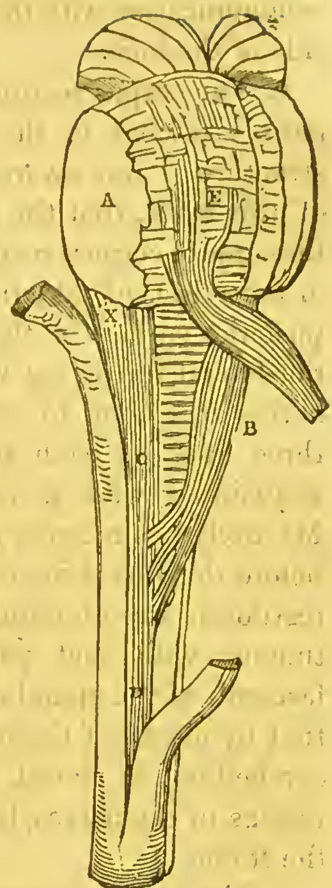
communication with the nerves of sense and motion of the same side of the body.

b. The corpus restiforme, or lateral part of the medulla oblongata, stretches to the cerebellum, and is incorporated in its structure. I was aware, and had described in an earlier edition of this work, that the tracts of medullary matter, which under the name of corpora restiformia extend upwards to the cerebellum, in their descent take in so much of the side as well as of the posterior surface of the spinal marrow as to include the posterior lateral furrow (at which the sentient fasciculi of the spinal nerves arise), or to occupy the surface of the cord for about three lines on each side of that furrow. But I was not acquainted with a very important anatomical fact, which Mr. Solly has recently discovered, and described in a paper read before the Royal Society, that the anterior fibres of the corpus restiforme stretch obliquely forwards so as to be distinctly continuous with that part of the cord from which the motor fasciculi of the spinal nerves take their origin. It thus appears, that by means of the restiform bodies, each hemisphere of the cerebellum is placed in mechanical communication with the origins of the nerves, both motor and sentient, of its own side of the frame.

c. The anterior pyramid displays in its course or distribution a remarkable difference from the rest of the medulla oblongata. It consists (like the corpus restiforme) entirely of white matter, which again, like the white nervous matter everywhere else, is resoluble into fasciculi, and then into filaments. These fasciculi may be pursued upwards towards the enkephalon, and downwards towards the spinal marrow. When pursued upwards they are found to plunge into the pons Varolii, then to separate, ascending still, but diverging slightly, and implicated in a remarkable closeness of interlacement with the cross fibres of the pons, which stretch from one hemisphere of the cerebellum to the opposite.

The adjoined figure represents a preparation made to show this and other points that bear a relation to it.

A represents the pons Varolii separated by cutting through its peduncles, with its superficial transverse fibres so far removed on the right side as to show the ascent of the fasciculi of the right anterior pyramid among the deeper seated ones, E.



As the fasciculi of the pyramid continue to ascend, they are joined by white filaments that appear to take an origin in the granular grey matter, which occupies the interstices between the transverse and ascending fasciculi. The augmented series of ascending fibres escapes from the pons at its upper edge, and finally spreads itself, diverging fan-like into the cerebral hemisphere of the same side. Thus is the anterior pyramid of one side placed in mechanical relation with the corresponding hemisphere of the brain.

But if we follow the pyramid in the opposite direction, and trace its descent towards the spinal marrow, a new and unparalleled disposition is found to take place. It is true, indeed, that a thin layer of the outer filaments seems to spread, some to the corpus restiforme, some to the anterior surface of the same half of the spinal marrow, but by far the greater part *bend over* [commonly in four fasciculi of unequal size, the uppermost the largest, and decussating obliquely the fasciculi of the opposite pyramid] *to the opposite half of the spinal marrow,* dipping towards its centre, into which they plunge in such a manner as to place themselves in mechanical relation both with the anterior and posterior [or both motor and sentient] parts of the opposite half of the cord.

B represents the left pyramid in its downward course dividing into fasciculi, which, crossing obliquely, go to implicate themselves with the central structure, C, D, of the right half of the spinal cord. This central structure, in its ascent, reaches X, where the fifth and seventh nerves rise. It is supposed, in the diagram, to be displayed by the removal of the anterior part of the right half of the spinal cord and medulla oblongata.

The decussation of the anterior pyramids exists I believe in all vertebral animals. I have seen it in the ox, the horse, the ass, the monkey, the dog, the kangaroo, the porpesse; and al-

though beyond these instances I have kept no written notes recording the fact, to the best of my recollection I have likewise seen it in birds, and in reptiles, and in fish.

The use of this remarkable transposition in the healthy œconomy is unknown. But the idea has long been prevalent that it plays an important part in cerebral disease, and that it has to do with the phenomena of hemiplegia dependent on injuries or disease of the enkephalon. It is a pathological law, that when a lesion of the cerebrum or cerebellum is limited to one side, and is of a nature to produce palsy, *that* palsy manifests itself on the opposite side of the body. I think I have successfully shown the manner in which the decussation of the anterior pyramid contributes to the production of this phenomenon. The theory which I have advanced, the reader will find explained at greater length in my Outlines of Pathology: the following are its elements.

1. When a cerebral lesion produces palsy, it cannot be supposed to act by interrupting the customary supply of cerebral power to the spinal marrow. For if it did, the removal of one hemisphere of the brain, or its lateral compression in an animal [from which a large part of the cranium has been removed], should produce hemiplegia; and an acephalous infant, or an animal with the cerebrum and cerebellum removed should be completely palsied, which is contrary to fact. Another consequence of this mode of influence, if it existed, would be, that in palsy strokes the parts the most remote from the brain would have their supply of nervous energy soonest cut off, which again is contrary to fact; inasmuch as the arm is in almost every case struck first and more severely than the leg, and when recovery takes place is slowest in being restored.

2. But if the cause of the palsy be supposed to be [as I conjecture], an actively depressing influence, propagated from the diseased brain to the nuclei of the segments of the medulla oblongata and spinal cord, the difficulties which attended the explanation under the first hypothesis are done away with. It is easy on this supposition to explain why the arm should be first smitten and most severely, and why the leg, if smitten at all, should be the first to recover. If the reader will refer to the diagram he may observe, that the fasciculi of one pyramid being produced into the centre of the summit of the opposite half of the spinal marrow, are implicated in the closest manner

with its structure. A shock transmitted through them would, it may be presumed, tell with the greatest violence where it would first fall, namely, on the segment of the spinal cord which originates the nerves of the neck and arm, and would tell *down* the cord in a proportion lessening with the distance from the insertion of the decussating fibres of the pyramid.

3. But how can such a shock so transmitted affect the nerves of the face on the opposite side to the cerebral lesion. The reader will see represented in the same diagram the ascent of fibres, from the point of implication of the fasciculi of the pyramid with the nucleus of the opposite half of the cord, towards the pons Varolii; the letter X is placed near the point of origin of the portio dura of the seventh nerve, the muscles supplied by which are so commonly paralyzed in cerebral disease. Is it surprising that the palsying shock falling at a point so near this, and in continuity with it by reflected extension of nervous fibrils, should propagate its depressing influence upwards, and paralyze the seventh, the eighth, the ninth, the fifth nerves, one or all? But nothing is commoner than these very incidents in hemiplegia, occurring alone or in conjunction with palsy of the arm. The lower extremity on the one hand, the orbital apparatus on the other, are the points of extreme remoteness from the centre, at which I have supposed the palsy shock to be delivered. It is certainly remarkable, and consistent with my hypothesis, that these parts should be proportionately so much seldomer affected than the face and arm. It has been objected to this theory, that in hemiplegia from cerebral disease, the leg is sometimes affected alone, or in a greater degree than the arm. If this occurrence were frequent, it would invalidate my hypothesis. Occurring as it does very rarely, it admits of many explanations, one of which is the following. Suppose the spinal cord to be predisposed to paraplegia, then the hemiplegic shock supervening and being slight, the phenomenon to be accounted for would naturally ensue.

4. But how is the fact to be accounted for, that lesion of one hemisphere of the cerebellum produces palsy of the opposite side? The reader will observe, on referring again to the diagram, the representation of a most close proximity and intertexture of the transverse fibres of the pons Varolii with those of the anterior pyramid in their progress through it [E] a closeness of interlacing nearly resembling that which obtains

in the spinal cord at the mixture of the filaments of the pyramid with it. Is it too bold an hypothesis to suppose, that where there is lesion of the cerebellum, the shock which it originates is capable of affecting through that closeness of interlacing the fibres of the pyramid of the same side, which being thus struck, carry the palsying influence downwards to the point of decussation?

Such are the heads of the hypothetical solution which I have proposed of the transmission of palsy to the opposite side of the frame. For the explanation of many of the attendant phenomena of great collateral interest, and a fuller exposition of what I have here stated, I refer the reader to my Outlines of Pathology.

Magendie found that division of the anterior pyramids, one or both, in animals, produced no further effect than a slight impediment in their movements forward; and that division of the entire half of the medulla oblongata produced palsy of the same side of the body.

II. The part of the enkephalon which is immediately superimposed upon the medulla oblongata, is the cerebellum.

The cerebellum in mammalia consists of three portions; the two lateral hemispheres namely, and the vermiform processes. In man, in monkeys, in the cetaceous mammalia, but in these alone, the lateral hemispheres are larger than the vermiform processes. The structure of the hemispheres and of the vermiform processes is the same. Its principle is seen upon making several vertical sections of a recent cerebellum. The appearances presented by either surface of such a section is termed the arbor vitæ; it shows the central part of the cerebellum to be composed of white nervous matter, which divides into thick plates (or branches as they seem in a single section) which subdivide into thinner plates of white matter. Over the final subdivisions one uniform layer of grey matter $\frac{1}{10}$ of an inch in thickness is disposed. Or the structure of the recent cerebellum may be thus imagined: one has to suppose a considerable quantity of thin grey nervous matter regularly folded in parallel plicæ, inclosing spaces, and the interior filled with white nervous matter.

We owe to Professor Reil the true analysis of the structure of this part: his papers on the cerebellum are contained in the volumes of his Archiven für die Physiologie, published in

the years 1807-8. I will not enter into the claims of Gall and Spurzheim as to the origination of this vein of inquiry. If Reil, which I think by no means proved, received from these anatomists his first notions of the structure, which he afterwards unfolded, it is at all events certain that he pushed his researches much further than Gall and Spurzheim, and that he obtained a physical demonstration of the correctness of the opinions which he advanced, which they had not arrived at. He discovered facts of structure which Gall and Spurzheim did not display; and whereas the latter relied upon a mode of dissection which was extremely liable to mislead, Professor Reil adopted a method which gave his results absolute certainty, and subjected them to positive proof or disproof.

The method employed by Reil consisted in hardening the nervous and membranous structure of the enkephalon by maceration in alkohol before dissection. Treated in this manner, the white nervous matter is brought to a consistence, in which it admits of being easily separated into threads and fasciculi, the disposition of which is easily verifiable. It is not every brain, however, that is fit for this proceeding. The best are, from persons under or about middle age, which have not been the seat of effusion; they should be taken from the cranium within a few hours after death. The mode of preparing the brain, is to place it immediately after its removal in a basin of water, and with forceps to draw off the arachnoïd membrane and pia mater: the water should be changed once or twice during this process (which occupies about a quarter of an hour) in order to get out the blood. The brain should then be transferred to a basin containing spirits of wine, in which it should stand for twenty-four hours. At that time the spirit requires to be changed, and once again at the expiration of a week. If the spirit is not thus changed the brain softens, and undergoes a kind of putrefaction. The induration proceeds from the surface inwards: the thinner portions, such as the medulla oblongata, are sufficiently hardened in a few weeks; the cerebellum in two or three months; the cerebrum requires half a year for the coagulation of its substance to reach the centre. However, the process may be accelerated by commencing the dissection as soon as the surface has hardened, and thus letting the spirit of wine earlier and more easily into the interior. This was the method, which, in his later dissec-

tions, Professor Reil employed. But it is evident that it would not suit a learner. A master only could judge how far he might proceed in this manner without risk of spoiling the evidence of structure in progress of being unfolded.

It has been sometimes urged as an objection to this method, that the structure which it brings to light may be an artificial result of chemical coagulation. There are, however, three satisfactory answers to this objection. The structure elicited is a fibrous structure, composed of a mixture of nervous matter and membrane : this is consistent with the analogy of structure in other parts of the nervous system. There are parts of the enkephalon, the medulla oblongata, and corpus callosum, for instance, where such a structure is already distinguishable in the natural state : and the first effect of the spirit of wine on the brain macerated in it is to make that structure come out all the more distinctly and strongly. Finally, whether the brain be macerated whole, or first cut in pieces and afterwards exposed to the influence of the spirit, the disposition of the fibres in the same part is found to come out in either case exactly the same.

Examined after this mode of preparation has been used, the cerebellum displays the following structure.

The superficial folded layer of grey substance remains granular, forming one expanded sheet, which there can be little doubt, like the grey and folded retina, in which the optic nerve terminates, is the most highly endowed part : the white matter which it encloses is doubtless nervelike in function as in structure ; it consists of threads, the office of which must be to transmit influences to and from the folded grey matter. The white matter tears first into broad plates or fasciculi ; these again tear into filaments, which appear likely to be divisible even beyond the point to which the eye can follow them. These white fasciculi are distributed in four orders.

1. One series is peripheral, and is placed immediately below and parallel to the folded grey matter. In the adjoined diagram the filaments which compose this series are represented by curved lines, extending from the laminæ of one side of a lobule to the neighbouring laminæ of the lobule next adjacent. They may serve to convey the following idea. Disposed parallel to the surface, they connect together near and remote parts of the folded grey matter of the same hemisphere.

Those nearest to the surface stretch from one lamina to the next: those which follow connect in succession laminæ more remote; till finally, threads of communication have been drawn under the whole periphery of the same hemisphere, connecting its most remote parts together.

2. A second order of fibres is that marked 1 in the figure; its production towards the median plane forms the transverse fasciculi of the pons Varolii; this part of the series of fibres alone is given in the diagram. The pedicle of the pons is there represented as truncated a little before its entrance into the cerebellum, in which its expansion forms the outer part of the white nucleus or stem of the arbor vitæ; followed to its furthest extent, its filaments are found to diverge and to spread to the lateral and upper parts of the cerebellum, where they reach the grey matter, passing in their terminal course between the filaments that form the first order of fasciculi described. The office of the second series is to form the great commissure [or Pons Varolii] by which the grey layers of the two hemispheres of the cerebellum are placed in mechanical communication.

3. The third series of fibres (2 in the figure) of the white nucleus of the cerebellum, is the production of the corpus

restiforme, which ascending and diverging, likewise distributes its filaments to cineritious matter, and principally to that of the upper parts of the cerebellum. In the diagram, the decussation with, or penetration of these fibres between the first series of filaments is represented. The office of this series is to place one hemisphere of the cerebellum in communication with the same side of the spinal marrow.

4. The fourth series of fibres and the innermost, which completes the stem of the arbor vitæ, is derived from the cerebrum; it is commonly called the pillar of the valve of Vieussens. Traced downwards from the cerebrum, it is found to be distributed principally to the grey matter of the under surface of the cerebellum. The white matter of the corpus fimbriatum is formed of part of this series; the filaments which enter that body at its fore and inner part, where it is open, seem in part to perforate its capsule and go beyond, in part to terminate in it. This fourth order of fibres has for its office to associate one hemisphere of the cerebellum with the cerebrum of the same side.

It is impossible not to anticipate that the knowledge of these anatomical facts will lead eventually to the determining with precision the functions of the cerebellum. What is wanted is a careful accumulation of instances of partial lesion of the human cerebellum, with the mental and bodily phenomena that have been associated with them. Such observations could not be made till something like structure had been discovered, and the physical connection of the different parts of the organ had been determined. How much knowledge is likely in time to be elicited by such a course of observation, is sufficiently clear from the following collection of results recently obtained by experiments on animals, and already to a certain extent confirmed by pathology.

The removal of the cerebellum in fish produces no further immediate effect than that of weakening the animal; frogs from which this organ is removed, show an indisposition to move unless irritated or placed in water, when their movements, though less lively than before, are not observed to be otherwise affected.

In birds and mammalia more important results ensue upon the injury or removal of the cerebellum, which it may be remarked appears not to be sensible to pain from mechanical lesion.

If the cerebellum is wounded upon one side, the animal appears to be generally weakened upon the same side: if the wound is deep, the body upon the injured side, according to Magendie, is rendered paralytic. If in a rabbit the upper and middle portion of the cerebellum is removed, the hind legs are observed to be spread, the fore legs are extended forwards in a state of rigidity: the whole attitude is that of preparation for moving backward or throwing itself over. After a short time the animal beats the ground with its fore paws, the hind legs not moving, and urges itself backwards. If the tail is pinched, the animal thus excited still exerts its fore legs only, and continues moving backwards. A deeper incision causes the animal to fall upon its side, the head is drawn backwards in a state of tension, the feet, and especially the fore feet, which preserve their rigid extension, are moved with violence.

The flight and the walk of pigeons are not affected by the removal of the upper part of the cerebellum. After a deeper section has been made, the bird totters, falls on its breast, rises again, and is in continual agitation. A deeper section still, causes it to walk and to fly backwards. After the entire removal of the cerebellum, the bird when irritated walks almost as usual; when thrown into the air, it moves its wings regularly, and alights upon its feet. A few minutes afterwards the legs become rigid, but the wings still move regularly if the bird be again thrown into the air: the legs remain in a state of tension, and the head continues drawn backwards till death. M. Fodéra saw all these phenomena succeed each other in the same bird, but each may be immediately produced by the fit incision. M. Magendie mentions the case of a young woman, who is affected with a nervous malady that forces her to run rapidly backwards, disregarding every peril.

The simplest explanation of the phenomena above described, is to suppose that an injury of the cerebellum to a certain depth produces a sensation analogous to vertigo; that the animal conceives itself either to be hurried forward, and makes a more or less perfect exertion to repel the imaginary force, or to be moving backward, and moves its limbs to a certain degree in correspondence. Either of these suppositions, which rest upon analogy, appear more likely to be just than the hypothesis that an animal exists under the influence of two impulses, one urging it forward, the other backward, and that the organ

of one impulse is removed on the partial destruction of the cerebellum.

M. Fodéra found similar phenomena to be produced upon the injection of a solution of camphor in oil into the abdomen in animals, either before or after the removal of the cerebrum, and remarked that they became more intense on removing a part of the cerebellum.

Lateral pressure of the cerebellum produces no effect that has been observed.

M. Magendie found results not less unexpected ensue upon a vertical division of the cerebellum, the crura cerebelli, and the pons Varolii.

If in a rabbit a section is made exactly in the median plane through the middle portion of the cerebellum, the eyes of the animal are observed to be in extraordinary agitation, and as if starting from their sockets; the animal inclines towards one side, then is suddenly thrown towards the opposite, as if unable to balance itself with precision: its fore legs are rigidly extended forwards, as if it were in the act of receding.

If a vertical section of the cerebellum is made, leaving one-fourth of the whole adhering to the crus of the right side, and three-fourths to the left, the animal rolls over and over incessantly, turning itself towards the injured side. The right eye is directed downwards and forwards, the left eye upwards and backwards. On making a similar section upon the left side the animal stops, and the eyes resume their natural direction.

M. Magendie was led to this discovery by accidentally dividing the crus cerebelli in a rabbit, upon which the same phenomenon occurs as upon dividing the cerebellum unequally. For eight days that this animal survived the injury, it continued to revolve upon its long axis unless stopped by coming in contact with an obstacle: when stopped, it ate upon its back with its mouth upwards. If the opposite crus is subsequently divided, the movement produced by the first experiment is stopped.

If the cerebellum is divided unequally, so as to produce a constant revolution towards the mutilated side, and the opposite crus cerebelli be subsequently cut through, an equilibrium is not produced, but the animal begins to revolve towards the side on which the crus is divided.

The whole of these phenomena are probably attributable

to a sensation analogous to vertigo: this conjecture at least appears strongly confirmed by the following case narrated by M. Serres.

A shoemaker sixty-eight years of age, of intemperate habits, after a debauch exhibited a kind of drunkenness which surprised his friends; instead of seeing objects turn around him, he seemed to himself to be turning, and in a few moments commenced revolving: placed in bed he continued to manifest this tendency till he died. Upon examining the head, an extensive lesion was found of one of the peduncles of the cerebellum.

II. The next part or series of parts in the investigation of the enkephalon, is the aggregation of tubercles, which are placed upon the crus cerebri; these are the corpora bigemina inferiora and superiora, and the optic thalamus. These have to be viewed in three relations; first, in reference to the origin of nerves; secondly, in reference to the formation and structure of the cerebellum; thirdly, in reference to the singular effects of their lesion, which add prodigious value to the facts last described. These effects are the following.

It is to be remembered that the tubercles placed between the cerebellum and the cerebrum, in part give origin to the optic nerves, in part send fibrils to the cerebrum.

On injuring the optic tubercle of one side in pigeons, blindness ensues of the opposite eye; and reciprocally on dividing one optic nerve, the under surface of the opposite tubercle, to which the nerve adheres, is found in a few weeks to waste.

On injuring deeply the optic tubercle in birds and mammalia, when the greater part of the brain, especially its base, has been left entire, the animal in flight or in its walk moves continually round towards the same side. In serpents and frogs the movement thus produced is towards the opposite side.

Pain and convulsive movements are produced by wounding this part of the enkephalon.

III. The cerebrum displays a structure exactly comparable to that of the cerebellum, and something more. Or the upper part, that is to say, the convolutions and the white matter which they immediately contain, have the strictest correspondence with the grey matter and four orders of white fibres in the cerebellum. Below these are other parts, which had better be first disposed of.

The reader is then to understand that the crus cerebri [the stalk on which, mushroom-like, each hemisphere of the cerebrum stands], is composed anteriorly of white fasciculi which are derived in part from the anterior pyramid, in part from the fibres which, originating in the grey matter of the pons Varolii, associate themselves with the pyramid. Behind this anterior and inferior crust of strong white fasciculi, a greyish layer alternated with white is placed: this is the production of the remaining part of the medulla oblongata. A thin layer of black matter, however, intervenes between it and the white crust; and the pillar of the valve of Vieussens passes it obliquely on the outside, making its way to the black stratum*. Above and at the back of these parts are placed the tubercles. These are masses of cineritious matter, the general structure of which is granular, at the same time that they are disposed to peel like an onion into concentric laminæ of loosely coherent substance. In one point they concur; fasciculi are produced from all of them which ascend, increasing the mass of fibres which are bending towards the interior of the hemisphere of the cerebrum. The tubercula bigemina are remarkable for their small size in man; in quadrupeds, they are actually as well as relatively larger; in the sheep, for instance, they have three times the volume of the same parts in the human brain. On the other hand, the thalamus in man is larger.

The thalami and the corpora striata are analogous parts, which crown in succession the ascending fibres, which we have traced thus far. Both of these parts have more or less the figure of a horseshoe, through the hollow of which the ascending fibres pass: but with this difference; the thalamus is the lowest of the two, and is a horseshoe open forwards; the corpus striatum situated above the other, has its perfect or closed convex end forwards, and is open behind. Both of these bodies are composed of grey matter; but the thalamus is of a lighter colour. Again, the corpus striatum is granular and structureless. The thalamus is granular, but like the lower tubercles peels into concentric laminæ. Both of these parts furnish a large augmentation of white fibres to form the ample white

* The reader is referred to the diagram of the origins of the cerebral nerves, in section VI of the present chapter, for a representation of some of the facts here mentioned; and to a folio fasciculus of plates of the brain and spinal marrow by the author.

nucleus of the cerebrum, which corresponds with the arbor vitæ in the cerebellum.

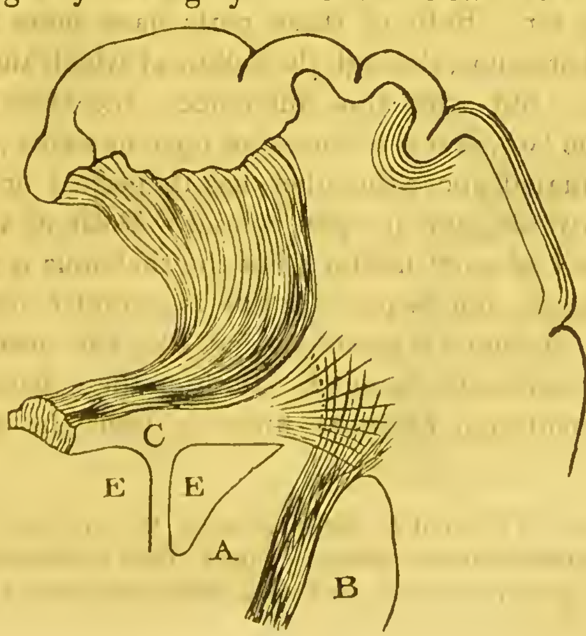
We may now analyze those parts of the cerebrum which have their analogues in the cerebellum. And first, the cerebrum is everywhere overlaid with folded grey matter. But this grey matter is not a simple layer, but consists, first, of an internal stratum, $\frac{1}{30}$ of an inch in thickness; secondly, of an outer stratum, that is $\frac{9}{200}$; there being, thirdly, interposed between the two a stratum of white matter $\frac{3}{200}$ of an inch in thickness. I have remarked that this division into three strata is very distinct in the posterior convolutions, but is only faintly traceable in the middle and anterior.

There then follow four orders of white fibres.

1. A series like the peripheral series in the cerebellum, of which the mechanical office is to connect together both near and remote parts of the grey matter of the same hemisphere.

2. A series analogous to the fasciculi of the pons Varolii, which stretch across from one hemisphere to the other, from grey matter to grey matter. These, where they meet, constitute the commissura magna cerebri, or corpus callosum. Like the fibres of the pons, they are easily followed to the upper and outer part of the hemispheres, but do not extend in equal quantity to the under surface.

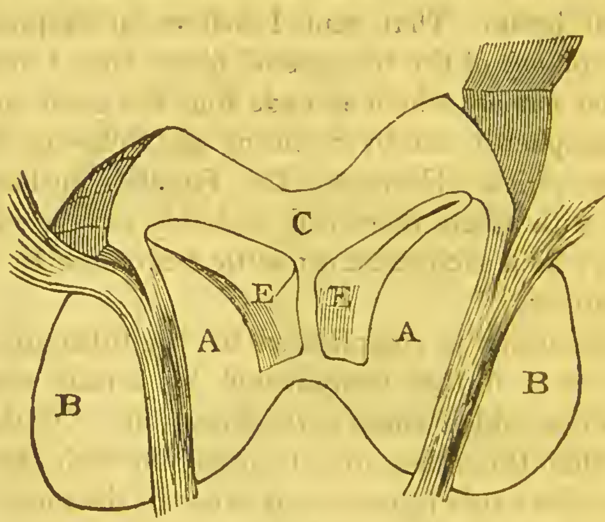
3 & 4. Fasciculi which extend from the medulla oblongata, and from the cerebellum, reinforced from the tubercles, and spread divergently to the grey matter of the entire circumference.



In the diagram at the foot of the preceding page, I have figured a partial view of these four orders of fibres, as they may be seen on a vertical transverse section of an hemisphere of a hardened brain near its middle.

At the circumference, about the middle of the figure, one set of the peripheral white fibres is indicated by concentric lines. The letter C is placed upon the great commissure, fasciculi of which are delineated, that may be followed into the upper convolutions of the hemisphere; the fibres which are figured between A and B, are the ascending fibres from the crus cerebri. A and B represent the section of the inner and outer portions of the corpus striatum. The letters E E are in the situation of the lateral ventricles.

There is a part which this figure is intended especially to explain, the structure of which it is very difficult to unravel. That part is situated at the upper border of the corpus striatum, where the divergent fibres that have ascended from the crus, mingle with and decussate the fasciculi of the great commissure. Perhaps I am speaking of the structure of this part too confidently,—although the view which I have adopted is that of Gall and Spurzheim [Reil speaking with great caution and doubt upon the subject], and has been borne out by repeated dissections of my own, from one of which the above figure is taken;—for a very eminent cerebral anatomist entertains a different notion of the formation of this part.



The adjoined figure [which is a corresponding section to the last) I took from a preparation, which Dr. Foville made in my

presence. It went to show, what Dr. Foville believes to be the fact, that the great commissure has nothing to do with uniting the circumferential parts of the hemispheres. He finds that in a firm fresh brain, if the inner convolutions of the hemisphere are raised from the great commissure [C in the figure], and the white substance exposed is slightly fissured by the nail, it *gives* in a remarkably even rent, which runs down between A and B [the inner and outer portions of the striated body], and may be pursued as far as the crus cerebri. The result of this dissection, if it be a true one, is to convert the great commissure from being the uniting fasciculi of the two hemispheres into a sort of crowning yolk or jugum to the production upwards of the medulla oblongata. In such a case, of course what one may conjecture to be probable goes for little: still it is something against Dr. Foville's dissection that this disposition of parts would be unanalogical. The cerebrum, which has so many parts in correspondence with parts of the cerebellum, would then want the most striking feature of all, the analogue of the pons Varolii. What enables me to disbelieve the correctness of Dr. Foville's demonstration is, that I think I see in what his error originated. If the reader will refer to the last diagram, he will observe, at the part where I have represented the fasciculi of the great commissure decussating the divergent fasciculi, a dotted line drawn, which gives the course of the rent, which Dr. Foville so dexterously produces in the recent brain. That rent I believe to be produced by the rupture of *one* of the *two* sets of fibres that I believe here exist (of that namely which extends from the great commissure into the hemisphere), and by favouring and following the course of the other series. However, Dr. Foville's authority is so great, that with others there will probably exist a doubt upon the subject, which each one must settle for himself by repeating these dissections.

As the cerebrum is complicated by the tubercular parts at its base, so is it further complicated by certain commissural bands of fibres which these parts throw out. Of these there are no less than three that are all connected with the thalami: one will be afterwards figured, as it exists in the mole: it forms a semicircular band of union between the two thalami, being in human beings the posterior fasciculus of the optic tracts; a second forms the posterior commissure, stretching likewise from

thalamus to thalamus; the third, originating in the grey matter of the upper part of each thalamus, passes as a white cord through it, and appears at the base of the brain; where having emerged and made an abrupt turn [which is called the corpus albicans], it re-enters the grey matter, ascends to the fore part of the lateral ventricle, then bends backwards along its floor, where the two are joined, under the name of the fornix, and so a third time unite the thalami: afterwards, as posterior crura of the fornix, the two leave each other, and in a circular sweep outwards, downwards, and finally forwards, expand into the grey matter of the fore and under part of the middle lobe, thus uniting that part with the thalamus of its own side. The same part (the fore and under part of the middle lobe) is again directly united to the same part of the opposite side by what is called the anterior commissure, which in its course has to pass through the highest of the tubercular parts, for such the striated body must be considered.

The phenomena which have been obtained by experiments on the cerebrum are full of interest in connection with those which have been described of the other parts of the enkephalon.

When the cerebrum has been removed in frogs and fish, they continue for a time to exhibit voluntary motion if roused.

When the upper part of the cerebrum is removed in birds and mammalia, the animal becomes blind, and appears stupified; but if it is roused, locomotion is performed with steadiness and precision; the animal walks when pushed, or if a bird, flies when thrown into the air. No further result is produced by the additional removal of some of the grey matter of the corpus striatum: but when a section is carried through the striated part, the animal springs forward, and continues to advance in a straight line till it meets an obstacle, when it still preserves the attitude of one advancing. This result ensues when the experiment is performed upon dogs, cats, rabbits, Guinea pigs, hedgehogs, and squirrels: the latter only in advancing cross their fore legs as in the action of climbing a branch, and if a stick be placed in their embrace, they ascend it.

Upon making lateral pressure on the hemispheres of the brain, no effect has been observed to ensue. Upon making vertical pressure upon the brain stupor takes place, which is

attributable to the compression of the medulla oblongata. It deserves remark, that when vomiting has been excited by an emetic substance, it is arrested by pressure made upon the medulla oblongata.

Reil describes his having examined the head of an idiot thirty years of age, who had been employed in the little traffic of neighbouring villages, in whom the middle part of the corpus callosum was entirely wanting, from an original malformation, as it seemed; for the convolutions were complete where a corpus callosum ought to have emerged to join the inner surface of the hemispheres.

It has been long known that a serous fluid is contained in the ventricles, and that the same is frequently found in greater or less quantity upon the surface of the brain as well as in the theca vertebralis; but till lately physiologists have been inclined to regard this fluid as a product of disease. M. Magendie has however recently shown that aqueous fluid uniformly exists in animals in full health, upon the surface of the brain and spinal cord and in the ventricles. This fluid serves to fill up the interstices which are left between the irregular surface of the nervous matter and the more even and spacious surface of the chambers which contain it, so as to support with an equal pressure the whole superficies of the brain and spinal cord. When this pressure is suddenly taken off by letting out the water, M. Magendie found that animals are affected with dulness and stupor: after twenty-four hours they are found to have recovered, the fluid having been reproduced. In two instances a contrary effect ensued, and for two or three days the animals were in a state of continual agitation and fury.

The water in the ventricles of the brain was supposed to be secreted by the pia mater which forms their lining membrane: upon the surface of the brain it was known to be contained between the arachnoïd and pia mater. M. Magendie discovered that the water upon the spine is likewise interposed between the same membranes: and described the channel, by which it flows from the fourth ventricle upon the spinal marrow; and proved by experiment the ready passage which a liquid may find from any point where this water is found to all the rest *.

* Journal de Phys. Exper., tom. 7.

SECTION V.

Of the relation of the Magnitude and Figure of the Enkephalon to Mental Development.

It does not admit of a doubt that the brain is the immediate organ of the higher mental endowments. The spinal marrow and the medulla oblongata are experimentally shown to be sufficient for sensation, instinct, and volition. The expanded cerebral masses with which they are crowned are the material parts, in which are seated reflection, moral impulse, and reason, which being awakened and fed through the senses, guide the will.

What, we are naturally led to inquire, are the relations of the higher mental endowments to these parts of the enkephalon? What are the conditions which render the one a fit recipient for the other, or which determine what kind of mind shall be developed in each species of animals, or in each individual human being?

In the first place, it does not appear that a greater quantity of brain necessarily goes with mental superiority. Were this the case, the whale and the elephant, whose brains are actually larger than the human brain, should have more than human reason?

Neither does the relative weight of the brain to the whole body appear to be the measure of mental superiority. The weight of the human brain is $\frac{1}{35}$ only of the weight of the entire frame, while that of a canary bird is $\frac{1}{14}$.

Neither even in conjunction with parity of form and structure does the last relation appear of any value. The eagle probably is as sagacious as the canary bird; but the weight of the brain of the eagle is only $\frac{1}{260}$ of its entire weight.

The same instances are sufficient to prove that the relation of the size of the brain to the weight of the spinal marrow and nerves does not determine the quality or extent of the mental endowments.

Is there, it may next be asked, any difference in the material of different brains? It is far from improbable that this may be the case; and that a difference of texture may be *one* of the elements by which the quality of mind connected with different brains may be determined. M. Magendie mentions that in aged persons, in whom of course the mind has lost

something of its strength and vigour, the specific gravity of the brain is 15 per cent. lighter than the brains of persons in middle life. On the other hand, no difference has yet been discovered in the quality of different healthy brains: and the brains of all animals in colour and consistence are remarkably like each other, and like the human brain.

Another point, which has to be considered, is the greater or less complexity and difference of arrangement of the component parts of the brains of different animals. And it certainly appears, that although examining this relation does not lead to any positive result (so many contradictory circumstances turning up in following it out), yet that upon the whole something like such a proportionate difference in the structure of the organ may be shown to exist, as may reasonably account for the difference of endowments.

The brains of fish [which is the lowest point in the scale at which we find adequate materials of comparison with the human brain], favour the idea, that complication of parts has to do with superiority of function. A fish's enkephalon, as we have seen, consists of little more than successive pairs of grey nodules, a pair for each pair of nerves or set of neighbouring pairs; as if there were a separate brain, or place of mental digestion for the impressions received by each cerebral nerve of sensation, and which issues the few impulses which that class of sensations excites in fish. Any general comparison of ideas or impressions being probably beyond the animal's powers, no common sensorium is established, the grey nodules being only lightly linked together by white nervous fasciculi. Or, as typifying a separate sensorium, a cerebellum is found in all fish; and in some, as in the carp, an anterior pair of nodules is likewise found, which may be called a cerebrum, not to mention the corpora mammillaria, and the pituitary gland, which are relatively of great size. When we contrast with the little and almost separate nodules of the fish's brain the human enkephalon, we are struck with the vast superiority of organization in the latter. For in the human brain, in the first place, the cerebellum has a wonderful amplitude of structure; instead of being, as in the fish, a nearly smooth layer of grey matter lined with white, it presents an enormous complication of parallel laminæ, an organization physically perhaps as superior to the fishes', as human reason is to a fish's instinct and cunning. The next parts in the fishes' brain, are the optic and the olfactory tubercles.

These parts we recognize in the human brain, the first as expanded into the lower tubercles and the optic thalami, the second as expanded into the striated bodies. These bodies give organs in human beings as in fish to the nerves of smell and of vision; but they are relatively larger in man than in fish, and instead of completing the cerebral structure, as they do in fish, they give origin to a new organization, throwing out a prodigious number of white fibres, which joining with others produced from the spinal cord, expand to form new and larger and voluminous masses, the cerebral hemispheres. An enormous organ is thus superadded in man to the elements of the skait's brain, to which superadded part the general analogy of structure throughout the nervous system makes it certain, that impressions are conveyed by the divergent fibres of the hemispheres, to be there the source of new mental affections, the resulting influences of which are to be retransmitted to the origins of the motor nerves to determine deliberate action.

It happens, however, that the progressive links which intervene between the brain of fish and the human brain, interfere to lessen the plausibility of the conclusion to which the preceding observations tend. For although in reptiles and in birds the cerebrum does not manifestly reach a much higher type than in fish, or show the distinct superposition of a new organ, or at all events in any preponderating mass or volume, yet in mammalia all the parts formed in the human brain make their appearance, and in several genera approach with great closeness to the type of the human structure.

It will, however, be asked, is there not in these intervening cases a corresponding improvement going on, a perfectioning of the mental endowments? Is there not in the genera, whose brains approach nearest the human brain, the closest approach to human nature? And is there not after all a prodigious difference left between the brains of all animals and the human brain?

To answer these questions *seriatim,* it may be first admitted as true in the main, that in the successive classes of vertebral animals upwards there goes with the expanding brain a sensible mental improvement.

Nevertheless, there are some striking instances in which the progression of organization does not seem to carry with it any thing like a proportionate mental advance.

The cetaceous mammalia have brains which, besides being

of large size, are nearly as complicated as those of human beings; they might therefore be expected to manifest a remarkable and distinguishing degree of sagacity. Endowed with a cerebrum and cerebellum approaching nearly in complexity and relative size to that of man, the dolphin ought to resemble in his habits one of the transformed personages in eastern fable, who contrived to betray under a brute disguise their human endowments. Something there should be very marked in his deportment which should stamp his essential diversity from the fishes, in whose general mould he is cast. His habits too, not shunning human society, render him especially open to observation; and the class of men who have the constant opportunity of watching his gambols in the deep are famed for their credulity, and delight to believe in the mermaid, the sea-snake, and the craken. Yet the mariner sees nothing in the porpesse or the dolphin but a fish, nor distinguishes him, except by his unwieldy bulk, from the shoal of herrings he pursues. The dolphin, in truth, shows no sagacity or instinct above the carp, or the trout, or the salmon. The latter even, which have but the poorest rudiment of a brain, are probably his superior in wariness and cunning.

The force of this striking instance, however, is materially lessened by the following considerations. In the first place we are not certain that the dolphin and the porpesse do not approach towards human feeling and reason considerably nearer than fishes. In the second place, the brains of these animals, although extremely complicated, display a marked difference in the arrangement of the cerebral convolutions, which are remarkably narrow and shallow. And finally, it is far from improbable that the brain has two relations, one only of which has to do with the mental development of the animal, while the other may bear a proportion to the degree of perfectioning of his physical frame, which, as it will appear in the sequel, is in part maintained in wholesome and harmonious action by impressions received from the brain. A complete double circulation, a higher standard temperature, the exact balance and consent of improved organs, may possibly want an expanded brain for their support.

But is there not in the genera, whose brains approach nearest the human, the closest approach to human mental nature? It is highly probable that this question ought to be answered in the affirmative. The principal objection which seems to me to lie

against it, is the extreme docility and intelligence of birds. The sagacity of the raven and of the magpie, the human sympathies [not the human language] of individuals of the parrot tribe, and the educableness of several of the smaller birds, do not fall far short of similar points in the dog, the horse, the elephant. Yet I am inclined to believe [difficult as it is to satisfy oneself on this question] that the higher animals generally have more of human feeling and character, than the most remarkable in this relation of the lower vertebral animals. The chimpanse and the pongo ought in this view to be the nearest to the human species, and it seems not improbable they will be found to be so.

But, further, does there not remain a prodigious difference between the brains of the higher animals and the human brain, and that in the parts of the brain, which belong to the highest grade of organization? This I think unquestionably is the fact. The hemispheres of the cerebrum and cerebellum, of the former particularly, in the extent, number, and depth of their convolutions, exhibit a vast superiority. The point of comparison which I would challenge should be the crura of the cerebrum and the tubercula quadrigemina on the one hand, and the amplitude of the superimposed hemispheres joined to the number, size, and depth, of the foldings upon its surface on the other. Thus in the human brain, although there is not absolutely any great division that does not exist in the brain of the dog, the elephant, or the monkey, yet there is a predominant development and physical superiority of those parts, which all analogy and reasoning lead us to suppose the seat of the highest endowments of the mind.

When we are satisfied that the higher endowments of the mind have their seat in the circumferential grey and white matter of the cerebrum and cerebellum, and that the greater development in man of these parts is causally connected with his mental superiority to animals, we turn to inquire wherein physically the mental organ of one human being differs from that of another, and whether there is discernible any difference of volume or figure of the human brain that bears an ascertainable relation to the differences of human character?

It certainly is analogically probable, that the superiority of one human mind over another goes with an increase of that development which marks the superiority of the human brain over that of animals.

We therefore inquire, whether the convolutions of the brain and the laminæ of the cerebellum are more numerous and deeper or more broad and prominent in persons highly endowed, than in those of an inferior cast of mind. With this inquiry the craniological theory of Gall and Spurzheim began; who, believing that there is no general augmentation of the cerebral masses proportionate to mental superiority, were led to entertain the opinion that there may be partial expansions of cerebral structure, corresponding with partial mental superiority; and concluded, that as the mind displays many different impulses and talents, each of these may have a corresponding organ and particular seat in the brain; and that as men's minds are always unequal, some endowments being of a better, some of an inferior order, it may be so explained, how the volume of the whole brain preserves an average seldom greatly departed from throughout the human race, there being in most instances partial force, partial feebleness, of development. Of the probable correctness of this view no doubt I think can be entertained. It has been asked indeed, in derision, where are seated the different organs of the brain that correspond with different mental affections; where the separation is to be found of one organ from another? It is true that such separations as the question supposes do not exist. But perhaps the very fact is in favour of the phrenological theory. Although the affections of the mind differ among themselves, although for instance the spirit of emulation is a different thing from philosophical talent, and the wish to see a family provided for different from the genius of a painter, yet are these different elements of mental impulse so combined in operation, that it is not unnatural to expect that their organs [assuming that they have distinct organs] should be very closely tied and linked by the ordinary apparatus of nervous communication. The convolutions of the brain may therefore fairly be represented to have quite as much separateness, quite as much conjunction, as are required by the phrenological theory.

The next step to be ascertained is, whether those who have followed out this theory have succeeded in determining by actual observation the locality of any mental organs.

There are evidently monstrous difficulties in the way of this investigation, of which the principal are these.

In the first place, it is extremely difficult to tell upon the living head which convolution is developed more or less than usual.

Secondly, human character is made up of the balance of numerous qualities; and it is most difficult to determine how much that is done or neglected by any individual, proceeds or is absent from the force of any one impulse or the weakness of another; not to mention how probable it would be that accidents of education, health, and the like, should interfere more or less to modify in every case the original disposition.

Thirdly, the difficulty has yet to be overcome of reducing the mind to its elements, and determining with any thing like certainty what are single mental principles, what compound results.

It is not therefore surprising that phrenologists should have made but little way towards mapping the brain with precision and success, supposing this object ultimately attainable, and their theory based in truth.

One of the steps preliminarily necessary, which has been already to a certain degree taken, is that the convolutions of the brain should be laid down in accurate drawings; and that not in a few instances only, but in a vast number, so as to determine what are the limits of variation in the figure and in the number of the convolutions. The phrenological anatomist should be as familiar with each convolution of the brain, as the surgeon with each nerve and artery. Having attained this knowledge, he would be so far competent to undertake the comparison of cerebral with mental development.

Much discrepancy of opinion exists as to whether phrenologists have or have not succeeded in determining any of the relations of the form of the brain to the mental powers.

I. *Of the Cerebellum.*—In this part the sexual appetite is supposed by phrenologists to be located. The justness of this opinion has always appeared to me doubtful. It may be confidently asserted that quadrupeds use the organs of smell and vision for discriminating the subjects of their appetites, both of food and desire. It is likewise highly probable that the part of the brain in which a nerve of sense begins, is that which digests the ideas and originates the impulses that follow from the excitement of the sense it conveys. But neither the optic nerve nor the olfactory communicate with the cerebellum; but both, especially the olfactory, take their rise in the tubercles that are immediately in relation with the cerebrum. The olfactory nerve in quadrupeds is even in part directly continued from the substance of the middle lobe of the brain. It is probable, so far as this reasoning has any

weight, that the impulses, by which the animal is led to those functions which preserve itself and its species, are originated in the cerebrum.

II. *Of the Cerebrum.*—The following considerations form a serious objection to the general phrenological division of the cerebrum, into an anterior and percipient and reasoning part, and a posterior part for disposition and impulse. It will be granted that animals have more affection for their offspring than reason. But quadrupeds in general, the horse, the dog, the sheep for example, have the posterior cerebral lobes small, the anterior lobes large. Again, on the general analogy of development, that which is formed latest in the embryo should have the highest function. But the posterior lobe of the brain is the last unfolded in the order of growth, the last part added to complete the improving organization. It is difficult not to allow these arguments some weight against the general impression that the forehead is the seat of reason.

Still the forehead certainly has its physiognomy, and may present an intellectual cast, or otherwise; but I do not think this has to do with its size, that is its height and breadth, but rather with its proportions: in general I think the remark will be found to hold good, that the size of the head, or of parts of the head, go for less than their fineness of shape; whether the relation be accidental or not, it is certainly generally true, that a well shaped and handsome *head* contains a better organized mind than a clumsy shaped cranium.

Phrenologists divide the forehead into two stories; to the lower they attribute the percipient faculties, with quickness of observation and rapidity of superficial combination. The upper story is of a more philosophical cast, and is supposed to be the seat of the more deeply reflective powers. I have seen some instances by which this distinction has been borne out: but others again, and some very remarkable ones, at variance with it: and upon the whole I think that the foreheads with most physiognomical promise of mental superiority, are those which resemble that of the mask of Newton, in which the region of the eyebrow is both broad and prominent, and the upper part of the forehead, without being deficient, is yet subdued and less in comparison.

In a very interesting paper by Professor Tiedemann, read before the Royal Society, July 14, 1836, the following remark

occurs: — "The brains of men who have distinguished themselves by their great talents are often very large. The brain of Cuvier weighed four pounds, eleven ounces, four drachms, thirty grains, Troy weight. The brain of Dupuytren weighed four pounds ten ounces." [The ordinary weight of the brain ranging between three pounds two ounces and four pounds six ounces.] In this paper Professor Tiedemann investigates the difference or resemblance between the brains of different families of mankind. The opinion towards which he inclines is, that the Negro is not inferior in cerebral development nor in mental capability to the other races. It is singular enough, however, that the facts adduced by Tiedemann lead to an opposite conclusion. He gives tables of the internal area of the skull in Europeans, Americans, Malays, and Negroes. Of the first, he adduces seventy-seven examples; of the second, twenty-four; of the third, thirty-eight; of the fourth, thirty-eight. The method of gauging each, which he employed, was to ascertain the weight of millet-seed required to fill it. I find by averaging his tables, that the European or Caucasian cranium contains forty ounces, the American and Malay thirty-nine, the Negro cranium thirty-seven only. In subsequent tables in the same Paper, the length and breadth of the European cerebrum are shown materially to exceed those of the Negro. And a very curious fact is added respecting the brain of the Bosjes woman, who was called the Hottentot Venus. The convolutions of the two hemispheres in this specimen [the dimensions of which are likewise of the smallest] are more symmetrical than is the case in European brains. This circumstance is an important approach towards the type of the cerebral organization of animals as distinguished from that of human beings. From the oran otang downwards, the two cerebral hemispheres of animals exhibit in their superficial markings great closeness of resemblance; whereas in European brains the resemblance of the gyri of the two sides is general only, and the details of their disposition vary remarkably.

The brain of the Hottentot Venus, marked with physical degradation in the symmetry of its convolutions, leads us to the conclusion, that the smallness of size which belongs to it is another sign of physical inferiority; at the same time that it strengthens the impression, which other considerations suggest, that the Æthiopian variety [from whatever cause it proceed] are mentally an inferior race.

SECTION VI.

Of the Functions of the Nerves.

The nerves are the media of communication between the central organs of the nervous system [the brain and spinal cord] and the rest of the frame. Their function in reference to consciousness is probably limited to the transmission of impressions, either of sense or motion.

There are forty pairs of nerves in the human body, of which thirty-one rise from the spinal marrow, and nine from the medulla oblongata. The former are called Spinal, the latter Cerebral nerves.

Nerves consist of the same material as the white matter of the brain: it is here as in the brain wrought into delicate filaments contained in sheaths of the finest membrane; several of these are contained in a common sheath, and form nervous fibrils: and a nerve consists of more or fewer fibrils connected by processes of the membrane already described, which is termed the neurilema: it is very vascular, and may be compared with the pia mater in the brain. A nerve has an outer tunic of a dense white glistening membrane, which is called its cellular tunic. The fibrils of a nerve are disposed parallel to each other, but they continually give off filaments, which join the adjacent fibrils: so that when a nerve is drawn out laterally, its structure appears reticular. All nerves partake of this structure. In the long nerves it is most evident near their origin. The optic nerve, which is short, is so reticular, that the appearance of strictly parallel fibrils is nowhere distinguishable in it.

Nerves extend from the spinal marrow and medulla oblongata to sentient surfaces and irritable parts. The first of these attachments is called their origin, the opposite their termination. The origin of a nerve is always in part from grey matter. The mode in which nerves terminate is not satisfactorily known, with the exception of the instance of the optic nerve, which expands within the eyeball into a sheet of grey matter; and of the instances in which voluntary nerves coalesce directly with fibrils of sentient nerves, a fibril originating at one part of the medulla oblongata, appearing to return under another character to attach itself again to the same part.

The tendency to a reticular structure which is met with in the composition of the nerves, shows itself again in the manner of their distribution.

In several remarkable instances, the fibrils of which adjacent nerves are composed are reciprocally thrown across from one to the other, forming what is termed a plexus. The nerves which proceed from the further side of a plexus may be more or fewer in number than those which enter it; but the essential result is, that nervous fibrils from different sources are brought together to form new trunks. What are termed ganglia have been thought by many to be exactly of the nature of plexuses. A ganglion is a small nodule, usually flattened, of an oval or circular shape, and of a reddish grey colour, which is found either on the trunk of a single nerve, or where two or more branches coalesce. Scarpa supposed, that a ganglion is but a bed of gelatinous membrane, in which the smallest fibrils of the nerves that enter it are arranged in new combinations. Others have supposed that nervous filaments originate in the grey matter of ganglions. It is not improbable that this may be the case, but the extreme minuteness of the fibrils in a ganglion renders it very difficult to determine whether it is so or not.

I. The nerves which rise from the spinal marrow are more uniform in their mode of origin, and simpler in their distribution, than those which rise from the medulla oblongata. Each spinal nerve arises alike by two roots, one from the anterior lateral, the other from the posterior lateral furrow. The filaments which compose the anterior root, are more slender and more numerous than those of the posterior root. The filaments which form the roots of the spinal nerves are followed with great difficulty into the substance of the cord. They appear partly to be continuous with the white fasciculi of the cord, partly to originate in the interior grey matter*. The two roots

* Among the anomalies mentioned by Magendie and Desmoulins respecting the spinal nerves, the principal are the two following. They state, that, in serpents, the spinal nerves have each but one root. Upon carefully opening the vertebral canal in a Python, I ascertained that this is not the fact, but that the nerves rise, as in other vertebral animals, by two roots. The second is, however, as correctly stated as it is extraordinary. In the lamprey, the spinal nerves appear to rise from the theca, not from the cord; that is to say, upon slitting up the theca, no filaments are seen extending to or from the cord. This I have found in the lamprey examined immediately after decapitation. I was greatly surprised to observe, upon irritating the skin of its tail, under these circumstances, that the caudal muscles acted. One might almost conjecture, that in the spinal apparatus of the

perforate the theca vertebralis by separate openings; then a spherical ganglion is formed upon the posterior root, and afterwards the two roots unite to form one nerve, which takes its name from the bone below which it emerges.

When a spinal nerve is divided in its course through the body, the parts supplied by it beyond the division are paralyzed—they lose sense and motion. If the two origins of the spinal nerves are exposed in a young animal, and separately divided, different effects are produced. The section of the anterior root deprives the part supplied by the nerve of voluntary motion, sense remaining; the section of the posterior root deprives the corresponding part of the body of sensation, voluntary motion being left.

These experiments were made by M. Magendie, and published by him in his Journal of Experimental Physiology. But many years earlier, Sir C. Bell had made experiments upon the spinal nerves, some account of which had been printed and circulated among his friends, as well as delivered in his Lectures. The following is an extract from this account: "On laying bare the roots of the spinal nerves," observes Sir C. Bell, "I found that I could cut across the posterior fasciculus of nerves, which took its origin from the posterior portion of the spinal marrow, without convulsing the muscles of the back; but that on touching the anterior fasciculus with the point of the knife, the muscles of the back were immediately convulsed." Sir C. Bell was carried by these experiments very near to the truth, but he failed at that time to ascertain it: he inferred from his experiments, indeed, that the anterior and posterior roots of the spinal nerves have different functions; but in the nature of these functions he was mistaken. Upon the anterior root he supposed both sensation and motion to depend: the posterior root he considered an unconscious nerve, the office of which was to control the growth and sympathies of parts. Before Sir C. Bell published any other account of the functions of these nerves, M. Magendie had given to the world the true theory of their uses.

The cerebral nerves taken together are by no means so simple or uniform, either in their origin or their distribution, as the spinal nerves. Yet the uses of several of them have long been

lamprey, the true nervous matter of the cord is disposed external to the membrane, which encloses the flat tape-like production, more like ligament than nervous matter, which is contained within the theca.

thought sufficiently explained by reference to the parts which they supply: and modern experiments have thrown no permanent doubt upon the correctness of opinions thus originally deduced from the consideration of anatomical structure. The cerebral nerves, the uses of which have long been known, belong either to sense or to motion.

II. The nerves of sense, included in this class, are, the first, the second, and the soft portion of the seventh.

The first nerve rises by three roots from the fore and under part of the corpus striatum, a layer of grey matter produced from which is contained within it, and extends as far as to the cribriform lamella of the ethmoid bone, where the size of the nerve is greatly increased by an additional volume of cineritious substance. The nerve now terminates in numerous fibrils, which pass through the foramina of the ethmoid bone, and are distributed plexiformly upon the septum narium and the adjacent surface of the upper turbinated bone.

As this nerve is the only nerve exclusively distributed to the nose, and as the sense peculiar to the nose is that of smell, anatomists consider this nerve to be the olfactory nerve.

The second nerve may be traced to the back part of the crus cerebri: it rises by a flat band of white fibrils, termed the tractus opticus, from the corpora geniculata and the thalamus nervi optici. The tractus optici unite at their commissure, and the second nerve is properly that part of the cord which extends from the commissure to the globe of the eye. Reasoning in the same manner as in the former instance, anatomists justly considered the second nerve to be the nerve of vision. There is much that is curious in the structure of the commissure: it may be better understood by reference to the figure at the end of this section [p. 262] than by any description in words. It appears that the outermost fibres of the tractus go to form the outermost fibrils of the optic nerve of the same side; that the next in order cross over to the optic nerve of the other side: that the innermost fibrils of the tractus of one side are continuous with the innermost fibrils of the opposite; and that in a similar manner a sort of loop is formed by the innermost fibres of either optic nerve.

The soft portion of the seventh nerve rises by two roots from the medulla oblongata. One set of fibrils passes between the

corpus restiforme and the production of the olivary tubercle to the floor of the fourth ventricle: another, which is more known, turns round the corpus restiforme, and reaches by a circuitous route the same origin with the first: the white striæ which form this second origin are an essential part of the calamus scriptorius. It is perhaps worthy of remark, that some of these coalesce at the median plane with fibrils from the opposite side, in a manner exactly resembling the junction of the innermost fibres of the two optic nerves: these nerves are probably the only nerves, which, when the two are simultaneously excited, convey but a single impression.

III. The cerebral nerves, which upon anatomical evidence have been considered voluntary nerves, are the third, the fourth, the sixth, and the ninth.

The third nerve rises by many filaments from the black matter in the crus cerebri: it is distributed to five muscles in the orbit, and sends a branch to assist in supplying the iris.

The fourth nerve rises from the opposite surface of the medulla oblongata, and supplies the superior oblique muscle of the eye.

The sixth nerve takes its apparent origin from the outside of the anterior pyramid at the edge of the pons Varolii, and supplies the abductor muscle of the eye.

It is remarkable, that the muscles of the eyeball have either no separate nerves of touch or filaments of this order incomparably more minute than other voluntary muscles receive, if indeed the threads derived by them from the fifth minister to this office. Is not this because their action is regulated by vision instead of by touch?

The ninth nerve rises from the fore part of the olivary tubercle: its numerous filaments are collected into two fasciculi, which unite to form one nerve. This nerve has long been termed the motor linguæ; it supplies the flesh of the tongue, and several muscles of the throat.

The offices of these nerves will be further considered in connection with the organs of the senses.

IV. We may next inquire into the history of the fifth nerve, and of the hard portion of the seventh.

The fifth nerve, the largest of the cerebral nerves, emerges

from the side of the pons Varolii, in two fasciculi, or roots, upon the larger of which a ganglion, termed the Gasserian, is formed; afterwards the fibrils of the nerve separate into three divisions. The smaller fasciculus passes below the ganglion, and afterwards associates itself with the third division of the larger. The correspondence in their mode of origin between the fifth and the spinal nerves has long been known to anatomists: Soemmering thus notices it; after describing the larger portion of the nerve, he adds, "minor nervi pars, majorem portionem descendendo obliquè præterit, neque ei fibras addit, *eum ferè in modum, quo prior radix nervorum spinæ medullæ ganglion non intrat**."

The first division of the fifth nerve is distributed to the ball of the eye and iris, to the lachrymal gland, to the Schneiderian membrane in the nose, and to the muscles and integuments of the forehead.

The second division of the fifth is distributed to the Schneiderian membrane, to the cheek and nostrils, to the palate, and to the alveoli of the upper jaw.

The third division of the fifth is distributed to the alveoli of the lower jaw, to the tongue, and the submaxillary and sublingual glands, to the integuments of the temple and of the chin, to the masseter, the pterygoïd muscles, the temporal, and the circumflexus palati.

The hard portion of the seventh takes its apparent origin between the corpus restiforme and corpus olivare. Having emerged from the cranium it reaches the cheek through the substance of the parotid gland, in which it divides into many branches, that radiate to be distributed to the cutaneous muscles and to the integuments of the face. These branches are noted for their frequent reticular junctions, which have obtained for the whole the name of pes anserinus; and are yet more remarkable for the occasional direct continuity (resembling that between the ninth and the gustatory in the tongue) of their smaller fibrils with those of the facial branches of the fifth.

Not more than sixteen years since, when the functions of the first, the second, and the auditory, of the third, fourth, and sixth, of the ninth and of the gustatory branch of the fifth were

* S. T. Soemmering de Corp. Hum. Fabricâ, tom. iv, p. 214. Trajecti ad Mœnum, 1798.

understood, and correctly described in physiogical treatises,—the functions of the greater part of the fifth and of the hard portion of the seventh nerves remained unknown, and lecturers on anatomy passed the subject over, as one which had hitherto baffled research.

It was in the year 1821 that the inquiries of Sir C. Bell into the uses of the fifth nerve, and of the portio dura of the seventh, were published in the Philosophical Transactions. Sir C. Bell's experiments were the following:—

"An ass being thrown, and its nostrils confined for a few seconds, so as to make it pant and forcibly dilate the nostrils at each inspiration, *the portio dura was divided on one side of the head;* the motion of the nostril of the same side instantly ceased, while the other nostril continued to expand and contract in unison with the motions of the chest.

"On the division of the nerve, the animal gave no sign of pain; there was no struggle or effort made when it was cut across.

"The animal being untied, and corn and hay given to him, *he ate without the slightest impediment.*

"An ass being tied and thrown, the superior maxillary branch of the fifth nerve was exposed. Touching this nerve gave acute pain. It was divided, but no change took place in the motion of the nostril; the cartilages continued to expand regularly in time with the other parts which combine in the act of respiration; but *the side of the lip was observed to hang low, and it was dragged to the other side.* The same branch of the fifth was divided on the opposite side, and the animal let loose. He could no longer pick up his corn; *the power of elevating and projecting the lip, as in gathering food, was lost.* To open the lips, the animal pressed the mouth against the ground, and at length licked the oats from the ground with his tongue. The loss of motion of the lips in eating was so obvious, that it was thought a useless cruelty to cut the other branches of the fifth*.

The inference, which Sir C. Bell drew from these experiments, was, that the branches of the fifth, which emerge upon

* Phil. Trans. 1821, p. 413. The passages in this extract which I have printed in italics mark the particular points in which Sir C. Bell's experiments either were incomplete, or admitted of a different explanation to that which he adopted.

the face to supply the muscles and integuments, are *for sensation and voluntary motion jointly;* and that the use of the seventh (the branches of which are distributed to the same parts) is to "*govern the motions of the lips, the nostrils, and the velum palati, when the muscles of these parts are in associated action with the muscles of respiration.*" In other words, according to Sir C. Bell, the seventh is the nerve of instinctive motion to the face, and the fifth of voluntary motion and sensation. Sir C. Bell, indeed, supposed that the hard portion of the seventh nerve was *one of a system* of nerves, which he termed *superadded* or *respiratory* (the others belonging to the system being the nervus vagus, the spinal accessory, the phrenic, and the posterior thoracic), that had the common office of ministering in different parts to instinctive action; and he appears to have relied especially upon the experiments which I have quoted, to illustrate and to support his theory.

The reader will see, that I have here quoted in Sir C. Bell's own words those experiments and conclusions of his, to which I adverted in a former section. I have, therefore, in addition, briefly to describe again my own counter-experiments, which were published in the first part of my anatomical and physiological commentaries in 1822.

1. I divided the portio dura in an ass, not on one side only, but on both: the instantaneous effect of the operation was to paralyze the nostrils and lips completely: the lips dropped from the teeth, and hung pendulous, not having muscular tone left to support their own weight. The lips remained perfectly sensible, but the animal made no use of them in attempting to take its food, or on any other occasion.

2. I divided the branches of the second and third division of the fifth at the foramina, where they emerge upon the face, in another ass: the result was, that the lips lost sensation; but although their apposition did not remain quite as exact as before, they did not lose their tone, or fall from the teeth, as in the first experiment. The animal, however, ceased to use its lips in taking up its food, and employed for this purpose the method described by Sir C. Bell.

No doubt I believe is now entertained, that the inference which I drew from these experiments is correct; namely, that the portio dura of the seventh nerve is a simple voluntary nerve, and that the *facial branches* of the fifth are exclusively

sentient nerves. The only circumstance which seemed to throw a doubt upon these conclusions, was the uselessness of the lips to the animal in gathering food, after the fifth alone had been divided. If the facial branches of the fifth be not, as C. Bell supposed, nerves of motion as well of sensation, how happens it that muscles, which they supply, cease to be of use on their division?

This seeming difficulty I discovered to be entirely removed upon referring to the history of cases of anæsthesia. In this disease, the sensation of the extremities is wholly lost, while their muscular power remains. Now it is remarkable, that in persons thus affected, the muscles of the insensible part can only be exerted efficiently, when another sense is employed to guide them and to supply the place of that which has been lost. A person afflicted with anæsthesia is described, in a case quoted by Dr. Yelloly in a very interesting memoir upon this disease, as liable "on turning her eyes aside to drop glasses, plates, &c., which she held in safety as long as she looked at them*." Instead, therefore, of being surprised that the animal in the experiment should cease to use its lips as before, supposing they had been deprived of sensation only, we could not consistently with analogy expect any other result.

In pursuing this subject, I was led to observe, that there are muscles which receive no branches from any nerve but the fifth; these muscles are the masseter, the temporal, the two pterygoïds, and the circumflexus palati. These muscles again I remarked are supplied with branches from the third division of the fifth, that is to say, from the particular division of the fifth, with which *the smaller fasciculus or root of the nerve* is associated. After some careful dissection, in the greater part of which I afterwards found that I had been anticipated by Palletta, I made out, that the *smaller fasciculus of the fifth* is entirely consumed upon the supply of the muscles I have named; to which it is to be borne in mind, that twigs from the ganglionic portion of the nerve are likewise distributed.

But I had already ascertained by experiment, that almost all the branches of the larger or ganglionic portion of the fifth are nerves of sensation. I proved this point by experiments upon the ass, the dog, and the rabbit, respecting the second and

* Medico-Chirurgical Transactions, vol. iii, p. 99.

third division of the fifth; in the pigeon, respecting the first division. It was therefore improbable that the twigs sent from the same part of the nerve to the muscles of the lower jaw should have a different quality, and be nerves of motion. For this function it was reasonable to look to the other nervous fibrils, which the masseter and temporal and pterygoïd muscles receive; in other words, *to the branches of the smaller fasciculus, or to the ganglionless portion of the fifth.*

By the experiments and reasoning which I have described, I thus established that the ganglionless portion of the fifth and the hard portion of the seventh nerve are voluntary nerves to parts, which receive sentient nerves from the larger or ganglionic portion of the fifth. This happened before the publication of M. Magendie's discovery of the parallel functions of the double roots of the spinal nerves; and without wishing to assert the least claim to that discovery, I will yet observe, that I was led by the well-known anatomical analogy between the fifth and spinal nerves, to conjecture nearly what M. Magendie proved, and was indeed actually engaged in experiments to determine the point, when M. Magendie's were published. I say nearly, inasmuch as subsequently to the publication of my experiments upon the facial branches of the fifth and seventh, I had been misled by the analogy of the third, fourth, and sixth nerves, to adopt an opinion respecting muscular sensation, which I did not correct till after I had seen M. Magendie repeat his experiments on the spinal nerves in this country*.

* The claims which have been put forward for Bellingeri as the discoverer of the uses of the fifth and seventh and of the spinal nerves are unfounded. The reader will see by the following extracts, which I quote from his inaugural thesis, which alone is prior in time to the publications of other claimants, how utterly vague and erroneous his notions on these subjects were: his anatomy however is very good, though his physiology is false.

"Partium vero, in quibus inseritur, vitæ organicæ præprimis conferre par quintum nobis ratio suadere videtur."—P. 121.

"Si igitur ubi solæ sunt quinti paris ramificationes, ut in ramo lacrymali, nasali, dentalibus, et palatinis, ibi sola est organica vita, nonne probabile redditur, quum in musculis et integumentis frontis, labiorum, nasi, et oris, universæque faciei distribuitur, ipsorum tantum vitæ organicæ famulari, animalem vero vitam, motum scilicet voluntarium, et sensum animalem ab adjunctis nervis pendere."

"Certe involuntarius iridis motus, involuntarius quoque musculorum internæ auris, regitur a quinto."

V. The eighth nerve consists of three parts, the glosso-pharyngeal nerve, the pneumo-gastric nerve or nervus vagus, and the spinal accessory.

The two first of these rise by many fibrils disposed in a line from the fore part of the corpus restiforme: upon each a small ganglion is formed. The smaller, which consumes the uppermost four or five fibrils, is the glosso-pharyngeal: it terminates in twigs distributed to the root of the tongue, and to the upper part of the pharynx. The latter branches are probably sentient and voluntary; the former sentient only. This inference I ground upon the following facts.

In every case where muscular action is proved to be under the voluntary control of a particular nerve, the mechanical irritation of that nerve directly after death will cause the muscle it controls to act: on the other hand, if a sentient nerve that is distributed in a muscle be thus irritated, no action of the

"Igitur et voluntarium musculorum facici motum, et animalem sensum tactûs a septimo pendere, consonum rationi videtur."

"Animi pathemata præprimis per ramificationes quinti paris mirè in faciem depinguntur."—P. 123.

"Jam vero ad maxillarem inferiorem gradum facimus, quem vidimus in anatome ramos tribuere musculo mylo-hyoïdeo, ventri anteriori digastrici, omnibusque musculis in mento ipsiusque viciniis existentibus; aperit inde maxillam inferiorem, et concurrit ad oris occlusionem, et diductionem, famulatur quapropter alimentorum sumptioni masticationi atque deglutitioni."—P. 156-7.

"Quintum denique par omnes involuntarios motus absolvere, constat observatu monstri a Lawrence descripti, in quo deficiente septimo pare, et præsenti quinto, cibórum assumtio, succus, masticatio, et deglutitio, perfecta est."—P. 158.

"Communem igitur tactum a quinto dirigi ultro concedam."—P. 160.

"Ubi exquisitior est tactus, ibi majores, multiplicatæque septimi sunt divisiones."—P. 161.

"Licet autem nervum hypoglossum minime gustui præesse defendam, puto tamen animalem tantum in linguâ absolvere."—P. 169.

"Præprimis animalibus functionibus in capite, facie, et collo, sensui scilicet animali, et motui voluntario præesse nervum facialem, ipsamet nobis suggerit anatomica structura."—P. 180.

"Profecto quum in cute capitis, faciei, et colli distribuitur [nervus facialis], animalem sensum perficere; quum vero in musculis omnibus externi capitis et externarum aurium, in cunctis fere faciei musculis, temporali excepto, in stylo-hyoïdeo, et digastrico posteriori, musculoque colli cutaneo insumitur, animalem motum absolvere ex iis quæ diximus de quinto probabile admodum redditur."—P. 181.

Caroli Francisi Joseph Bellingeri, dissertatio inauguralis, anno 1818.

muscle follows. Now I observed, that on thus irritating the glosso-pharyngeal nerve in an animal recently killed, the muscular fibres about the pharynx acted, but not those of the tongue.

The nervus vagus, or pneumo-gastric nerve, distributes branches to the larynx, trachea, and lungs, to the pharynx, œsophagus, stomach, and duodenum, to the liver, the spleen, the kidneys. The fibrils which it distributes to the larynx and pharynx and œsophagus are nerves of sensation and motion.

The spinal accessory nerve, which is associated with the two preceding, rises in great part remotely from them: its origin takes place by many fibrils from the side of the medulla oblongata, and from the back part of the spinal marrow in the upper part of the neck behind the ligamenta dentata, and not far from the posterior roots of the spinal nerves, which furnish a few filaments to it. It gives a branch to the nervus vagus, and fibrils to the pharynx, but the greater part of the nerve assists the spinal nerves in supplying the sterno-mastoïd muscle and cucullaris. Upon irritating this nerve in a living animal, pain is excited: upon irritating it in an animal recently killed, the muscles it supplies are convulsed. We may suppose, that rising between the two roots of the spinal nerves, it partakes of both their functions; but why it should not, like the phrenic or the ulnar nerve, rise in the ordinary manner from the spinal nerves, no cause that will bear examination has been assigned.

VI. Of the sympathetic nerve.

The sympathetic is a slender nerve which descends upon or near the side of the vertebræ, from the foramen caroticum in the temporal bone to the os coccygis. Its colour is greyer than that of other nerves, and its texture seems to contain throughout a portion of the substance, which is elsewhere peculiar to ganglia. The whole nerve is besides studded with ganglia: there are three in the neck, and one to each of the vertebræ below; on the os coccygis the nerve on one side joins with its fellow to form a single ganglion. In the canalis caroticus the nerve which ascends as a plexus round the artery has again one or more small ganglia.

From this nerve are derived in the neck and canalis caroticus, branches to the great vessels and to the heart; in the

chest, branches which supply the viscera of the abdomen; in the abdomen, branches which supply the pelvic viscera. Their function is unknown. I have divided the nerve on each side in the neck, but no symptom followed. The ganglions and the nerve itself appear to be sensible in a very low degree, if at all. Yet the sensations which we experience in the intestines must be communicated through this nerve; and the action of the fibres of the bowels may be influenced through it; and the impression which can be made upon the action of the heart after decapitation, by crushing a portion of the spinal cord, must be transmitted through its influence. The name of the nerve expresses the conviction of anatomists that it is used to associate the affections of different parts; and till the real functions of the nerves were ascertained, physiologists were pleased with dilating upon the connections, which in health and disease are kept up between all the organs of the frame through the agency of this nerve and the nervous system generally. But the shallowness and conjectural nature of such remarks become strikingly apparent, when they are placed by the side of rigorous deduction from experiment; and it becomes proportionately easier to understand, that a plain avowal of ignorance is more creditable and more useful to the progress of science, than pages of ingenious hypotheses.

But will not the origin of the sympathetic throw some light upon its function? It seems to spring from the sixth nerve, and from the Vidian branch of the fifth, and to be reinforced by fibrils from the portio dura, the eighth, the ninth, and all the spinal nerves, and from both their roots, but principally the anterior. The nerve then is in fact but a collection of branches from almost every nerve in the frame, which join it at the adjacent ganglia? This may appear to be true, but it is not the whole truth. The sympathetic certainly *gives* branches to different nerves as well as receives them from the same. The adjoined drawing, which I made from two very careful dissections, will serve to illustrate this remark.

Fig. 1, represents the junction of the sympathetic with the sixth in the cavernous sinus. *a*, is the carotid artery; *c*, the sympathetic nerve distributed upon and to it; and *b*, the sixth nerve (the letter being placed at its cerebral end), both giving and receiving filaments.

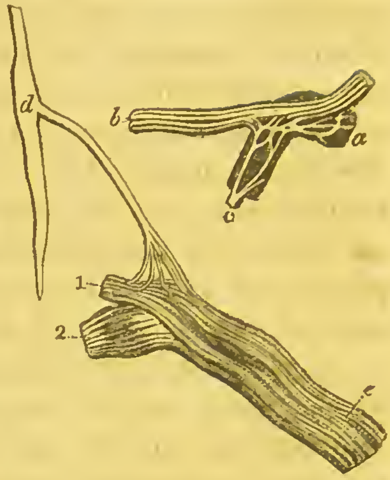
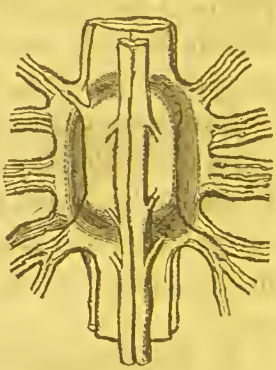


Fig. 2, represents the junction of the sympathetic with the second lumbar nerve. *d*, is a ganglion of the sympathetic: *e*, the spinal nerve; 1, its anterior root; 2, its posterior root with the ganglion. The connection between the nerves is of the same description as in the former instance.

Till recently, it was still a question of doubt, whether the series of double nodules in articulate animals is or is not analogous to the spinal cord and medulla oblongata of vertebral animals, or whether it bears an additional or stricter correspondence with the double chain of ganglia of the sympathetics. The valuable researches of Mr. Newport into the anatomy of the nervous system in some articulate animals, but principally in the sphynx ligustri, seems to me to remove this difficulty. The figure which follows represents one view of a segment of the double cord of the sphynx ligustri. I have selected it from among Mr. Newport's figures, as showing particularly well the triple disposition of parts, which the central organ of the nervous system in the sphynx displays. That central organ, instead of consisting of a single pair of nervous ropes studded with pairs of nodules, is formed of no less than three pairs. The first, that nearest the integuments of the abdomen, is more immediately connected with, or the seat of the nodules. The second, smaller and flat, is laid upon the first. The third, of much slenderer fasciculi, is superimposed upon the second. There is something remarkable in the disposition of the fine nerves which proceed from the third pair: they appear to have a visceral distribution, and to go especially to the respiratory tubes.



Of the different conjectures, which Mr. Newport offers, as to the nature of this third pair of nervous ropes, I think there can be no doubt, that the comparison of them with the sympa-

thetics indicates their just relation. We thus have in the nervous centre of the sphynx ligustri all the elements, or analogues of all the elements, met with in vertebral animals, and located in a parallel order. For, in vertebral animals, the spinal canal is the securest region for lodging the double cord: but in insects the belly. Let us then substitute for the ideas and expressions of anterior and posterior, in reference to the place and aspects of the elements of the double cord, the terms peripheral and axial. To describe by means of these terms the order of the elements of the nervous system in man, we have, as the peripheral formation, the double cord of sensation with its ganglionic nerves; but we find the same idea followed in articulate animals, in the peripheral double cord distinguished by pairs of nodules (ventral indeed, whereas in the former instance it is dorsal): but in each nearest the surface of the frame. Next follow in each case double tracts, which, as in vertebral animals they are experimentally proved to be for motion; so can it not be doubted that in insects they are appropriated to the same function. Thirdly, in man, the double chain of the sympathetic forms a smaller double cord, that is axial. Can it reasonably be doubted that the smaller axial double cord of the sphynx ligustri has a corresponding office, and forms its sympathetic?

I am tempted to add a figure of the origins of the cerebral nerves, as they appear when made out in the substance of the human enkephalon hardened in alkohol. It will serve to illustrate several of the remarks which I have already had occasion to make, and I shall again find advantage in having it to refer to.

A. Represents the under part of the corpus striatum.

B. The thalamus nervi optici.

C. The corpus geniculatum externum.

D. The corpus geniculatum internum.

E. The corpus bigeminum superius.

F. The corpus bigeminum inferius.

G. The exterior stratum of the crus cerebri cut through so as to show the termination of

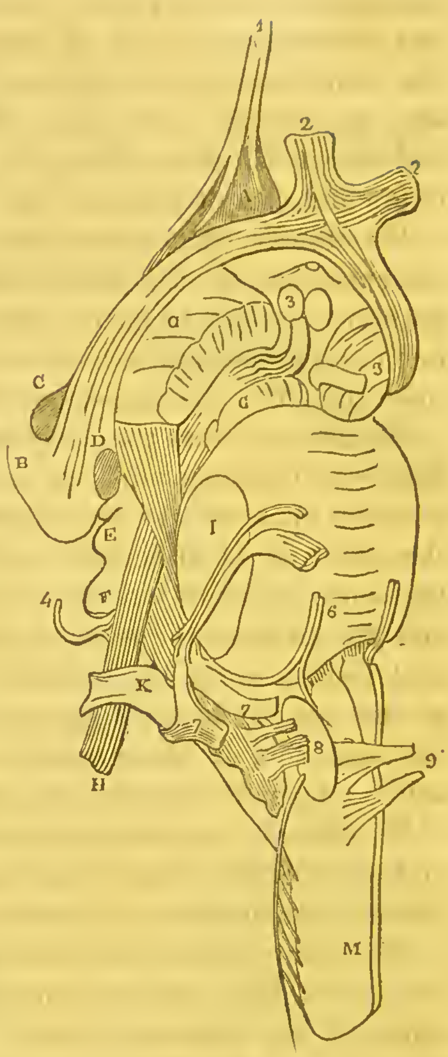
H. The upper pedicle of the cerebellum.

I. The pons Varolii cut through at the part where the fifth nerve perforates it.

K. The corpus restiforme.

M. The spinal marrow.

The nerves are marked by the numbers which designate them, all but the fifth, of which the lettering has been omitted: but the reader will recognize its two portions displayed in their course through the pons Varolii. The hard and soft portions of the seventh have both the figure 7 upon them.



The first impression upon looking at such a dissection, and still more upon looking at the undissected base of the brain, is, that there is no method or order or principle of arrangement followed in the origins of nerves. I believe, however, that such a principle exists, and that the following general expression conveys it.

I believe that the observation will be found to be correct, that nerves of motion take their rise from the same region or segment with those sentient nerves which transmit the impressions, by which their action is usually regulated. The correctness of this statement, as it respects the spinal nerves, will not be disputed. It is owing to this circumstance, that when in an animal just killed, the spinal cord has been divided in the neck and in the back, on irritating the integument of either foot, that foot is retracted as promptly and to the same extent, as if the spinal cord and the medulla oblongata were entire. Upon the same principle, if a pigeon's enkephalon is removed, with the exception of the tubercles and crura cerebri, which are to be left attached to the eyeballs by the third pair of nerves, on irritating the part of the divided optic nerve adherent to the insulated segment of

enkephalon, the iris acts. In the preceding figure, the third and fourth nerves, one of which governs the motion of the iris, while both guide the eye to suit the wants of vision, are seen to rise near the optic. But the principle which I have laid down is more strikingly illustrated by referring to the origin and uses of other nerves.

We observe, that the smaller portion of the fifth rises from the upper part of the medulla oblongata close upon the greater portion; and we recollect, that the sense of pressure upon the teeth and gums, and of muscular exertion attending it, depends upon the latter, the muscular effort itself upon the former.

We observe, that the large root of the fifth and the portio dura rise together; and we recollect, that the delicate sense of touch upon the eye and eyelids depends upon the first, and the action of the orbicularis palpebrarum on the second; that the sense of touch in the nostrils depends upon the first, and the action of the muscles of the nostrils upon the second; that feeling in the lips depends upon the first, and the action of the muscles of the lips upon the second; and, finally, that the sensation of those muscles, which the second sets into action, depends upon the first of the two.

We observe, that the portio dura rises near the portio mollis; and we recollect, that the motions of the ear depend upon the former, and the sense of hearing upon the latter.

We observe again, that the sixth nerve rises near the fifth; and we recollect, that it directs the eye outwards towards the orifice of the lachrymal gland, the secretion of which is under the control of the fifth.

It is unnecessary to point out in detail how completely the glosso-pharyngeal and the pneumo-gastric nerves support the principle which I have endeavoured to establish. That every nerve cannot be arranged under it (for I know not by what means it can fairly be made to include the first and the ninth) does not, I hope, render the observation valueless.

It remains to define, which ought to have been done before, what are meant by sentient and voluntary nerves. By sentient nerves, I mean those, the division of which is followed by instantaneous loss of sensation in a part; by voluntary, those, upon the division of which, the will ceases to influence the muscles they supply. What part nerves play in sensation and voluntary motion, whether they merely transmit impres-

sions, or have some further agency, is a matter of speculation. The former opinion is perhaps the most plausible: it is borne out by the analogy of the general structure of the nervous system; and it is strikingly consistent with the very curious fact, that after the amputation of a limb the patient always experiences for a time sensations, which, taken alone, would persuade him that his limb was still alive, and formed part of his frame.

SECTION VII.

Of the Influence of the Nervous System on the Vegetative Functions.

This subject, perhaps of equal practical importance with the relation of the brain and nerves to consciousness, has not hitherto been studied with equal success. Yet valuable light has been thrown upon it by the researches of Legallois, Brodie, Magendie, and Wilson Philip.

That the tears will flow on one affection of the mind; that the heart will beat with violence under mental excitement, or cease to beat under depression; that a disagreeable image conjured before the fancy will produce nausea and vomiting; that distress or hope will destroy the appetite; that fear will act on the kidneys and the bowels, are instances of the influence of the nervous system over the organic functions.

They exemplify likewise the law, which seems to be universal in this class of phenomena. The nervous system determines the rate at which each function proceeds, the quantity of secretion, the frequency of involuntary muscular contraction. The function is performed through other influences; its time only is measured by the nerves.

The elements in vegetative life, upon which the influence of the nerves has been ascertained, are involuntary motion, secretion, growth.

1. *Involuntary motion.* — Legallois described contradictory effects upon the heart's action supervening upon mutilation of the central organs of the nervous system. Dr. Wilson Philip has shown, that the abstraction of the brain, done with little

violence in a cold-blooded animal, has no immediate influence on the heart; that crushing any considerable part of the brain or spinal marrow stops the heart's action.

2. *Secretion.*—The experiments of Brodie and Magendie show that the gastric secretion is formed after the pneumogastric nerves have been divided near the stomach. The secretion of the kidney I found to take place after its nerves had been divided, and portions of the length of a third of an inch had been removed.

Dr. Wilson Philip's remarkable researches into the influence of the pneumogastric nerves on digestion, led to the following singular conclusion: — If these nerves are divided in the neck, and the divided extremities turned aside, digestion does not take place; but if the cut ends of the nerves are left in complete apposition, or nearly so, digestion is then performed. The influence, as it would appear from these experiments, which excites or permits the gastric secretion, being of a nature to pass across from one extremity of the nerve to the other. Nothing similar happens in the voluntary nerves. Having divided a voluntary nerve, I left the two ends in apposition; and here I found, that mechanically irritating the cerebral portion produced no action in the muscles supplied by the remote half.

One of the points that are unexplained about nerves, is their *looping*. In the tongue and in the face, branches of the fifth form loops with filaments of the ninth and seventh. And if the microscopic observations of MM. Prevost and Dumas are to be relied on, looping is the mode in which nerves terminate in all the voluntary muscles. However this may be, certain it is, that loops of nerves are never more freely met with than about organs of secretion. Thus, for the supply of the lachrymal gland, a loop is formed between a branch of the facial nerve and the lachrymal division of the fifth; for the parotid, there is a junction of filaments of the superficial temporal branch of the fifth with the facial; for the sublingual and submaxillary, the junction of the chorda tympani with the gustatory; among the abdominal glands, all is plexus, network, and looping, or, to use a still more exceptionable expression, nervous anastomosis.

It is not uninteresting under this head to notice the indifferent application of nerves that have been by some considered

as of opposite classes to the same function. The electric shock which the torpedo and the electric eel communicate, are phenomena that would fall under the same head, as far as regards the nervous influence, as secretion. Now in the gymnotus the electric organ is disposed along the side of the body, in the vicinity therefore of the spinal cord; accordingly, it is from the spinal nerves the organ receives its supply. In the torpedo, on the contrary, the electric organ is situated by the gills, nearer therefore to the cerebral nerves; accordingly, it is from this source that the electric organ in the torpedo has its supply. But the nearest nerves are the fifth and pneumogastric; and it is not from the latter alone — but from the pneumogastric quite to the same extent or more — that the branches of the electric organs are sent off; the two instances proving very clearly, that, as far as the production of animal electricity is concerned, the spinal nerves, and the fifth and the eighth, are equally efficacious.

3. *Nutrition.* — Magendie found, that division of the fifth nerve in rabbits, within the cranial cavity, produced a sensible effect on the nutrition of the eye, but with a remarkable difference. If the nerve was divided near its origin, partial opacity of the cornea alone followed; but if the nerve was divided on the temporal bone, where the ganglion of Gasser is, the experiment including the destruction of that ganglion, deep-seated inflammation of the eye and suppuration and loss of the organ followed.

These remarkable experiments seem to show, that the ganglions have greater influence over nutrition than the brain. Still the first appears to show, that the withholding the cerebral influence is felt in the nourishment of parts.

Another instance of the same kind came under my own observation. A young man from a fall suffered a fracture of the upper lumbar vertebræ. The accident produced palsy of the left leg; and after a few days, inflammation of the bladder followed. He died shortly after. On examining the vertebral canal, the cauda equina on the left side was found to have been partially crushed and bruised. The injury, however, lay between the origin of the nerve and its ganglion.

I mention this case as parallel to the first of Magendie's experiments, having little doubt that the inflammation of the bladder which always supervenes upon serious lesion of the

spinal marrow, as well as the inflammation of the lungs and pleuræ which follows division of the pneumogastric nerves in the neck, or the gastritis which ensues upon the same, are likewise resultant phenomena of the interruption of the customary supply of nervous influence.

In parts from which the general supply of nervous influence is withheld or lessened through palsy, it is a fact generally known, that common irritants applied to the skin produce more than usual mischief: — thus, vesication of the skin of palsied limbs is produced by hot water, or when the hand is held to the fire, at a temperature which would not inflame the skin when endued with sensibility.

CHAPTER IX.

OF THE ORGANS OF THE SENSES.

Our sensations are of two kinds; one internal, the other external. The first informs us of the inward condition of our bodily frame; the second communicates ideas of the world around us.

Our inward sensations comprise an infinite variety. They are, first, those which have to do with the appetites — hunger, thirst, and the like: secondly, sensations akin to the first that lead to the relief of our physical necessities — such as the sensation which calls for the expulsion of urine and the like: thirdly, those which attend over-exertion of any organ — in the muscles, fatigue — in the eyes, weakness — in the brain, confusion and sense of inability to further labour: fourthly, every variety of pain, of which the final cause seems to be to give us information of one or more organs being in a state of actual or threatened lesion. It is wonderful how finely the occasions, on which pain arises in different parts, are adapted to their conservation. The skin is exquisitely alive to cutting or burning; while many inward parts — the brain for instance, the bowels, the ligaments — are not sensible to either of these injuries. The latter have no occasion for this mode of sensibility for their protection: the impressions which excite it cannot reach *them* till they have first penetrated the skin, when the requisite warning must have been felt. On the other hand, the skin, as it requires to be extensible to allow of the play of the joints, and even of the different degrees of plumpness or obesity which the frame may assume, so does it convey no sensations to us when it is stretched within moderate degrees. The skin therefore is not calculated to give us warning when a joint is in progress of being strained, and its ligaments are in danger of being ruptured. How then are *they* guarded, these impassive sinews, which will bear the knife or the cautery without

feeling? They are so arranged as to feel, when placed upon the stretch, a new sensation, unlike others, sufficiently instructive of the kind of lesion threatened.

It may be said, in reference to the internal senses, that the frame is in the completest health and condition, when they are not excited. The healthiest self-feeling, is the absence of all inward sensation. The buoyancy of the frame in its strength and vigour results from the absence of all inward feeling to weigh it down :—when each muscular action, unchecked, elastic, the effort not felt, conveys a consciousness of power and of facility of exertion.

The external sensations belong to eight classes. Of these, six have special organs, or are capable of being excited in certain parts only, that are physically adapted to receive the impressions that excite them : two that remain are of a vaguer character, and are diffused more generally.

The six senses which have special organs are the following : —

Senses.	Organs.
1. Sight	the eye.
2. Hearing	the ear.
3. Smell	the nose.
4. Taste	the tongue and soft palate.
5. The sense of effort	the voluntary muscles.
6. Touch	the skin and tongue.

The senses, which are diffused, are —

7. The sense of heat and cold, and of general contact.
8. The sense of motion.

SECTION I.

Of the Organ of Vision.

The retina, as the thin terminal expansion of the optic nerve is called, which, cup-like in shape, is filled with transparent humour, has the wonderful property of communicating to us sensations of colour, when adequate impressions are made upon it. A blow upon the eye causes it to appear to flash fire ; and pressure on the side of the eyeball excites the sensation of

coloured circles. The impressions by which we see, although of an incomparably more delicate nature than the preceding, yet, like them, are mechanical impulses upon the retina. They are produced by light.

Light consists either of imponderable and infinitely minute material particles emitted from luminous bodies, or of undulations of an ethereal medium supposed to pervade all space. A succession of particles on the one theory, or of undulations on the other, constitutes a ray of light. Rays of light move only in straight lines: their velocity is so great, that they travel from the sun to the earth, a distance of 95,000,000 miles, in $8\frac{1}{8}$ minutes.

Luminous bodies are such as [on the first theory] continually throw off particles of light. Transparent bodies are those which permit the passage of light. Opaque bodies are those which obstruct it. No material substances appear to be perfectly opaque or transparent. Leaf gold sensibly transmits a greenish light: on the other hand, a depth of seven feet of water intercepts one half of the light which passes through it. Light moves in right lines; but its path is liable to be altered in two ways — by reflection namely, and by refraction.

All visible bodies that are not luminous, are seen by means of rays that, having impinged upon, are thrown back from their surface. If a ray of light falls upon a surface perpendicularly, it is reflected perpendicularly. If a ray of light falls upon a surface obliquely, and is reflected, the angles which it forms with a line vertical to that surface, are called the angles of incidence and reflection. The law of reflection requires that the angles of incidence and reflection be equal, and that the incident and reflected ray be in the same plane with the imaginary vertical line. The term reflection is usually confined to those cases in which the rays are thrown back in a definite order, either in lines parallel to each other, or uniformly convergent or divergent. To produce this species of reflection, a surface must be highly polished, in order that there may be uniformity in the angles at which the greater part of the rays are returned.

Refraction takes place, when a ray of light passes from one transparent medium into another of different density at any but a right angle. If the direction of the ray is vertical to the surface of the new medium, no refraction takes place, and the

continued path of the ray is a right line continuous with its former course. If the ray enter the new medium obliquely, it pursues a new course, being turned or refracted towards the perpendicular, when the second medium is of greater density than the first; but refracted from the perpendicular, in the opposite case. Transparent substances have been supposed to refract, in the ratio of their density and their combustibility. The extent of the refraction produced by the same medium depends upon the angle at which a ray enters it. All rays of the same kind transmitted by the same substance, form with the perpendicular an angle of refraction, the sine of which has a constant proportion to the sine of the angle of incidence.

Light is not simple. The white light of the sun admits of being decomposed, through the different refrangibility of its elements, into rays of different colours; which again are capable of being recombined, when they form again white light. The primitive colours which form white light are three—red, yellow, and blue. The intermediate tints of orange, green, indigo, and violet, are combinations of the primitive colours. The colour of luminous bodies depends upon the quality of the light they emit. The colour of bodies that are not luminous, when seen by white light, results from their absorbing some and reflecting others of the elementary rays.

The compound nature of white light is physiologically illustrated by the phenomena of convertible colours. If the retina is fatigued by fixing the eye for some seconds upon a coloured spot strongly illuminated, upon averting it, the field of vision appears haunted by a spot of the size of that recently looked at, but of a different colour. If the experiment is repeated with different colours, the eye being directed after each trial to a perfectly white surface, the colour of the spectrum is found to have an invariable relation to the colour of the spot by which the eye has been fatigued. The secondary colour is called the convertible or accidental colour of the first. The term complementary, often used as synonymous with the terms already mentioned, is better than either. The new colour is, in fact, the complement of the original colour to white; or deduct the colour with which you would fatigue the eye from white, the convertible colour will certainly be composed of the remaining elements of white light. Fatigue the eye with red,

for instance, the colour of the spectrum produced will certainly be a blueish green. Each point of the retina, it thus appears, has a separate perception of the different elements of white light, at the same time that it receives their collective impression; so that when its sensibility to one is exhausted, it can discern, with unimpaired distinctness, the rest of the group.

The effect produced upon the retina by rays of light of different refrangibility, may, in one sense, be considered arbitrary. We may imagine, on the one hand, that there are beings who would derive sensations of light from the deoxydizing ray, beyond the violet of the prismatic spectrum; and we find, upon the other, that there exist human beings to whom either extreme of the spectrum is alike. The following statement, which I extract from the Medico-Chirurgical Transactions, describes the common form of defective vision.

"My eyes (says the writer of this narrative) are grey with a yellow tinge round the pupil. The colour I am most at a loss with is green, and in attempting to distinguish it from red, it is nearly guess-work. Scarlet in most cases I can distinguish, but a dark bottle-green I could not with any certainty tell from brown. Light yellow I know; dark yellow I might confound with light brown, though in most cases I think I should know them from red. All the shades of light red, pink, purple, &c., I call light blue: but dark blues and black I think I know with certainty, Though I see different shades in looking at a rainbow, I should say it was a mixture of yellow and blue, *yellow in the centre and blue towards the edges.* I have red crimson curtains in the window of my bed-room, which appear red to me in candle-light and blue in day-light. The grass in full verdure appears to me what other people call red, and the fruit on trees when red I cannot distinguish from the leaves, unless when I am near it, and then more from the difference of shape than colour. A cucumber and a boiled lobster I should call the same colour, making allowance for the variety of shade to be found in both; and a leek in luxuriance of growth is to me more like a stick of red sealing-wax than any thing I can compare it with."

The writer of this narrative mentions that a similar defect in vision had occurred in other instances in his family. At Dr. Nicholl's suggestion he made the curious observation, that on fatiguing his sight at different times with gazing upon spots

of red and green on a white ground, the eye became painfully affected, but no accidental colour made its appearance*.

When the sensations of colour are congenitally defective, it is of course extremely difficult to determine in what the defect consists. The patient has no means of comparing the sensations which he experiences with those of perfect vision, and of telling how far his sight agrees with that of other men. It appears however certain, that in these instances the extreme colours of the spectrum are confounded: the eye observed to be unable to discriminate green and orange, these two colours appear the same. It is probable that the yellow of both is the only colour seen with a distinctness approaching our own perceptions; and that the blue and red are little more than degrees of shade or darkness.

The simplest instance of vision is the perception of the blood-vessels upon the retina. They may be brought into view in the following manner:— Let one eye be closed, and a candle held near to the other, but to one side, so that the flame may not occupy any of the central part of the field of view. If the candle thus held be kept stationary, nothing occurs but a diminution of the sensibility of the retina to light: but if the flame be continually moved up and down through a small space for a short period of time, the blood-vessels of the retina, with all their ramifications, and exactly as they are represented by the accurate Soemmering, are projected in the field of view, and become distinctly seen. This curious phenomenon, observed by Purkinjè, has been best explained by Mr. Wheatstone.

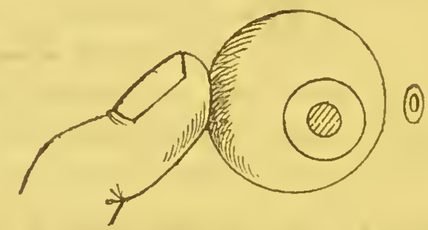
Mr. Wheatstone supposes, that the appearance seen is the shadow of the vascular network; and that it becomes visible through being made to fall *intermittently* upon the same points of the retina, or in succession upon different points.

Mr. Wheatstone recommends the following contrivance for showing a variation of this experiment. A circular plate of metal is to be used, about two inches in diameter, blackened upon one side, and perforated at the centre with an aperture of the size of an ordinary pinhole: to this is fixed a similar plate of ground glass. On placing the aperture between the eye and the flame of a candle, and keeping the plate in motion,

* Medico-Chirurgical Trans. vol. ix, p. 363.

so as to displace continually the image of the aperture on the retina, the blood-vessels are seen distributed as before, but more brightly, and the spaces between their ramifications appear filled with innumerable minute tortuous vessels before invisible. It is remarkable, that in this, as well as in the former experiment, in the very centre of the field of vision, there is a small space in which no trace whatever of vessels appears.

It has been stated to be the particular endowment of the retina, that, when adequate impressions are made upon it, sensations of colour are produced. A very trifling addition to this statement contains the enunciation of a principle, upon which almost all the phenomena of vision depend, and to which the entire construction of the eye has reference. *When an impression is made upon the retina sufficient to produce sensations of colour, the colour appears projected in a line vertical to the point of the retina which has been excited.* Thus, if pressure be made with the finger upon the outside of the eyeball, a circular spec-

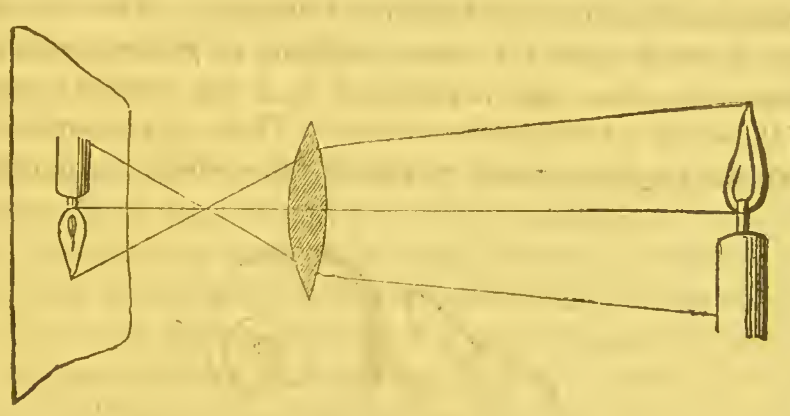


trum is seen in the direction of the nose; if the pressure is made at the upper part of the eyeball, the spectrum appears towards the cheek; if below, towards the eyebrow. The spectrum is always opposite to the point compressed, or is projected in a line vertical to the point of the retina which is excited to sensation. I shall have occasion, afterwards, to mention the conclusive experiment made by Scheiner, through which this law of vision was established. In the mean time, the ruder experiment of my own, which I have mentioned, may serve to satisfy the reader of its justness.

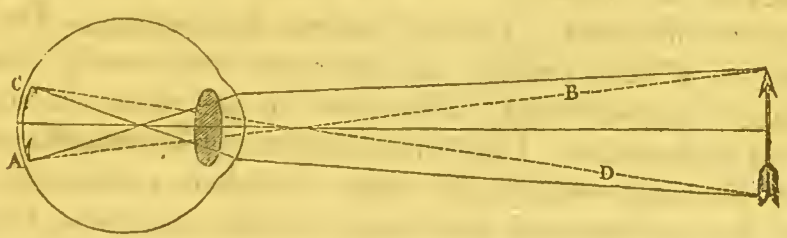
It appears that by this endowment of the retina the *direction* is rigorously determined, in which we can see by each point of its surface. The upper part, when excited, perceives sensations of colour in a direction *downwards,* or may be said to *see* downwards, the lower part upwards, the inner outwards, the outer

inwards. Now the retina is to be used in giving us notions of the visual direction of objects, which are to correspond exactly with the notions which we derive from the sense of touch. Accordingly, we find placed before the retina a series of media, the effect of which is to produce true vision by means of the law of direction above stated.

The globe of the eye is filled with transparent humours: the effect of these humours is parallel to that of a common double convex lens of glass. Interpose such a lens between the flame of a candle and a sheet of paper, and if the latter be at the proper focal distance, the result is the arrangement of the rays entering the lens from the candle in an inverted position, thus —



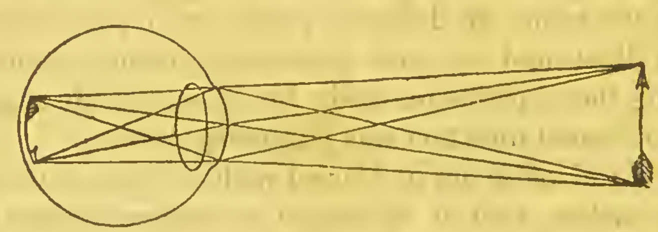
Let me substitute for this diagram, one of the eye in vision, in which the dotted lines A B, C D, are meant to be vertical to the points A and C, and are to be understood to be so.



The rays from the object towards which the eye is turned, are represented as reversed upon the retina. This fact, which is easily shown in the eye of a dead animal, is commonly considered as a defect in the mechanism of sight requiring compensation. So far, however, is this from being true, that the inversion of the picture is the only means by which correct

vision could have been attained. For the upper part of the retina is that which alone, by the law of vision above stated, can see downwards; or, to speak with more precision, that can have sensations of colour excited in it, the apparent direction of which is downwards. The rays from the lower part of the object must therefore be brought to the upper part of the retina, as the only part at which they can excite a just impression of the direction of the point from whence they have come. To refer to the diagram:—Excite the point A of the retina any how, so as to produce sensations of colours, they will be projected in the line A B: excite C, the colours will be seen in the direction C D. But A B is in the true direction for the upper part of any object looked at: the ray of light from the upper part of the object must therefore be brought to A. C D again is the true direction for the lower part of the object; the ray proceeding from the lower part must therefore be brought to C.

In the diagrams which I have given, I have represented a single ray as proceeding from each point; but it is evident that many rays enter the eye from each point of an object. It is another office of the refractive media of the eye, to bring all the rays which enter the pupil from a single point to a focal point upon the retina. A diagram, therefore, of the passage of each ray of light through the humours of the eye must be at least as complicated as the subjoined figure, to convey an adequate notion of their agency.



It is evident how essential it is to vision, that the rays of light *from each point of an object* should be collected upon one point of the retina; for, if they reached several points with perceptible intervals, they would necessarily give rise to as many different perceptions of the object, and all in different directions, as the points upon which they might fall; or, if they were vaguely spread over a circle instead of occupying a

point, there would be an end, through their mutual intersections, of distinct vision. The second of these two consequences is illustrated by the defective vision of myopic and presbyopic eyes.

The myopic eye is the common short-sighted eye of young persons; in it the cornea and aqueous humour are too convex, and the lenses of the eye are therefore too highly refractive. The result is, that parallel rays of light entering the pupil are brought to a focus before they reach the retina; and having crossed and begun to disperse again, are spread upon the retina in a circle instead of a point. This defect is corrected by the use of glasses of a divergent quality, which spread the rays a little before they enter the too powerfully refractive eye. Without glasses the myopic eye sees distinctly objects which are near; for from these the rays which enter the pupil are already divergent.

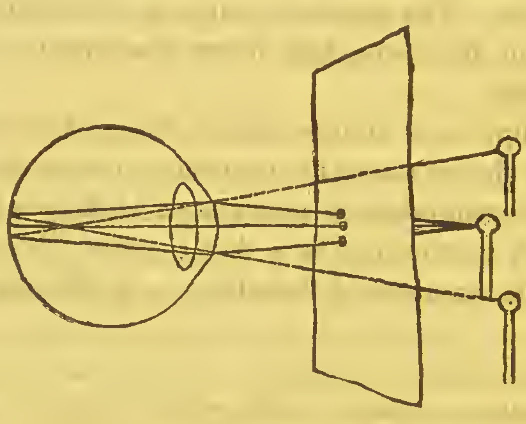
The presbyopic eye is the cause of imperfect vision in old people: in it the aqueous humour is not sufficiently convex; the humours of the presbyopic eye are therefore not sufficiently refractive, and can bring to a focus upon the retina no rays that are at all divergent when they reach the pupil. Distant objects however, from which the rays are parallel, the presbyopic eye sees without assistance. To enable such an eye to see near objects, a lens of a convergent quality must be made use of.

The former point to which I adverted — the consequence, namely, of the rays of light from a single point of the object reaching the retina at different points with perceptible intervals — is illustrated by, and gives me a fitting opportunity of describing the experiment made by Scheiner, through which the law of visual direction was originally shown.

If the head of a pin be viewed with one eye at the distance of three inches, that is to say at a distance nearer than the limits of distinct vision, the pin-head appears large and imperfectly defined, the outermost part of the cone of rays, which enters the pupil from each point of the object, having been too divergent to be brought to a focus on the retina. A well-constructed eye looking at an object at this distance is in the situation of a presbyopic eye directed to any but remote objects. Now, if a card pierced with a single pin-hole be interposed between the eye and the head of the pin, the outline of

the latter is at once rendered clear and definite. The minute hole through which it is seen excludes the cone of rays, allowing one ray alone from each point of the object to reach the retina.

But the object may be seen by rays passing through the upper part, or the middle, or the lower part of the pupil, according as the card is raised or lowered; and the apparent place of the object may by this means be made to shift: the object appears to rise when the card is lowered, to sink when it is raised. Or, instead of one, let three minute pin-holes be made close to each other on a vertical line. The diagram which is adjoined is meant to illustrate all the phenomena which are then observed.



By this experiment a clear picture of the object is produced upon three parts of the retina. The consequence is, that three distinct objects are seen; when it is easy to ascertain, by closing the pin-holes in succession, that the lowest of the three objects results from the impression made upon the upper part of the retina, and *vice versa*. In other words, each point of the retina upon which you collect the rays from the object, sees the object in a direction vertical to it, agreeably with the law which has been already introduced to the reader's notice on other evidence.

Let me now describe the nature of the refracting media within the eye, which we have hitherto viewed as comparable to an ordinary double convex lens.

The refracting media in the eyeball are the cornea, the aqueous humour, the lens or crystalline humour, and the vitreous humour.

The cornea is formed of a transparent dense elastic laminated substance, being a segment of a smaller sphere than the globe of the eye. As its surfaces are nearly parallel, it deserves perhaps rather to be described as a piece in the case of the eye, than as part of the mechanism by which light is modified in its passage to the retina. The cornea is .03 of an inch in thickness at its centre.

The aqueous humour is a liquid, which consists of water impregnated with albumen, gelatin, and muriate of soda: its refractive power, according to the observations of Sir David Brewster and Dr. Gordon, may be estimated at 1.3366, that of water being 1.3358.

The form of the aqueous humour depends upon the parts which confine it. The aqueous humour is contained between the cornea and the lens, and forms a meniscus. Its specific gravity is 1.0088.

The crystalline is a double convex lens, of which the anterior surface is flatter than the posterior: its substance is gelatinous, and of much denser consistence at the centre than near the surface: it is contained in a thin capsule. Its composition, according to the analysis of Berzelius, is as follows:

Water	58
Peculiar matter	35.9
Muriates, lactates, and animal matter soluble in alcohol	2.4
Animal matter soluble only in water with some phosphates	1.3
Portions of the remaining insoluble cellular membrane	2.4
	100.0

The refractive power of the different parts of the crystalline humour, according to Sir David Brewster and Dr. Gordon, is as follows:

Refractive power of the outer coat of the crystalline	1.3767
Refractive power of the middle coat of the crystalline	1.3786
Refractive power of the central part of the crystalline	1.3990
Refractive power of the whole crystalline	1.3839

The specific gravity of the crystalline is 1.0765.

The vitreous humour is a liquid resembling the aqueous humour; but it is contained in a proper capsule termed the hyaloïd membrane, from which innumerable membranous processes pass inwards to form a series of cells in which the liquid is lodged; the vitreous humour nearly fills the eyeball. The

lens is imbedded in its fore part; the hyaloïd membrane upon approaching the margin of the lens splits into two layers, one of which passes behind the lens adhering to its capsule, the anterior passes upon the fore part of the lens and becomes identified with its capsule. Air may be blown into the circular channel between the two layers of the hyaloïd membrane at the margin of the lens: this channel is termed the canal of Petit.

The refractive power of the vitreous humour is 1.3394. In specific gravity and chemical composition it resembles the aqueous humour.

The object sought and attained by the employment in the eye of several media of different density and refractive power appears to be the following.

Light when refracted by transmission through a single transparent substance is more or less separated into its constituent colours. This effect is called the dispersion of light; it arises from the different refrangibility of different coloured rays. The dispersive power of different transparent media is not proportioned to their refractive powers, nor does it affect the different elements of light always in the same ratio. Accordingly by combining, or rather opposing to each other lenses of different dispersive powers, while the required amount of refraction may be obtained, the opposite dispersions are neutralized. This is the principle upon which achromatic telescopes are constructed. In the structure of the eye a parallel adjustment is certainly made, although in what way exactly has not yet been explained in a satisfactory manner.

As the joint effect of the transparent media above described and of the figure of the retina, the rays that enter the pupil from a given point of an object are collected without dispersion into a focus upon that part of the retina, which is vertically opposite to that point: and thence, through the operation of the law before explained, we have intuitive knowledge of the true direction of any point of an object at which we look, that is at a proper distance and adequately illuminated. These premises being admitted, it is evident, that every object, at which we look, must have a definite visual magnitude, inasmuch as the apparent size of an object must exactly depend upon the space which its outline occupies upon the retina. Now the same object at different distances will, it is easily shown, oc-

cupy a larger or smaller area in the retina. The nearer it is, the larger will be that area; the more remote, the less. Here then is a provision by means of which we may learn to judge of the relative distance of a known object. But has the eye no original measure for, or perception of distance? It appears by a remarkable case, recorded by Cheselden, that it has not. That philosophic surgeon, after performing the operation of couching, studied the effect of the first visual impressions upon his patient, which he describes in the following words.

"This young gentleman either had been born blind, or had lost his sight so early, that he had no remembrance of ever having seen: the blindness arose from a cataract, or opaque crystalline, in both eyes. Like other persons who have ripe cataracts, he was not so blind but that he could discern day from night, and for the most part in a strong light distinguish black and white and scarlet. When he first saw, he was so far from making any judgment about distances, that he thought all objects whatever touched his eye (as he expressed it), as what he felt touched his skin. He knew not one thing from another, however different in shape or magnitude; but upon being told what things were, whose form he before knew from feeling, he would carefully observe that he might know them again. Two months after being couched, his attention seems to have been drawn to the effects of painting, which he then first and at once comprehended: but even then he was no less surprised, expecting the pictures would feel like the things they represented, and was amazed when he found those parts, which by their light and shadow appeared round and uneven, felt only flat like the rest; and asked which was the lying sense, feeling or seeing?

"Being shown a small miniature of his father, and told what it was, he acknowledged a likeness, but was vastly surprised, asking how it could be that a large face could be expressed in so little room, saying it should have seemed as impossible to him, as to put a bushel into a pint. At first he could bear but very little light, and the things he saw he thought extremely large; but upon seeing things larger, those first seen he conceived less, never being able to imagine any lines beyond the bounds he saw. The room he was in, he said, he knew to be but part of the house, yet he could not conceive that the whole house could look bigger. Before he was couched, he

expected little advantage from seeing worth undergoing an operation for, except reading and writing; for he said, he thought he could have no more pleasure in walking abroad than he had in the garden, which he could do very safely and readily; and even blindness, he observed, had this advantage, that he could go anywhere in the dark, much better than those who can see: and after he had seen, he did not soon lose this quality, nor desire a light to go about the house in the night. He said every new object was a new delight, and the pleasure was so great that he wanted ways to express it: but his gratitude to Mr. Cheselden he could not conceal, never seeing him for some time without tears of joy and other marks of affection. A year after first seeing, being carried upon Epsom Downs, and observing a large prospect, he was exceedingly delighted with it, and called it a new kind of seeing. And now being lately couched of his other eye, he says that objects at first appeared large to this eye; but not so large as they did at first to the other; and looking upon the same object with both eyes, he thought it looked about twice as large as with the first couched eye only, but not double that he can any ways discover *."

By part of these interesting details it appears evident, that the sense of sight originally gives us no information respecting either the distance or real magnitude of objects, and that there is no essential resemblance between the ideas communicated by vision and by feeling. The early years of life are instinctively employed in learning to interpret the visible signs of external objects. For this purpose, as soon as there is intelligence in an infant's gaze, it extends its hands to touch and examine each object in succession which attracts its notice.

The eye has no original measure for distance, and gives us no certain notion of real magnitude. When the eye is fixed upon a point on the wall of a narrow chamber, or in the vault of heaven, it seems to command an oval or circular area of equal visual dimensions: a foot-rule under these circumstances, held at the distance of a few inches before the eye, measures equally the side of the room or a segment of the firmament.

When the actual size of an object is unknown to us, and we look at it, if at a certain degree of remoteness, with both eyes,

* Phil. Trans. abridged, vol. vii, p. 491.

or if near with one eye only, we judge of its distance by the greater or less indistinctness of its colour and outline. We judge of its real magnitude by a calculation founded upon its *apparent* size and probable distance. Hence we are liable to continual mistakes on these points. An Englishman in the clear atmosphere of Italy supposes distant objects to be nearer to him than they are. We think the moon larger when near the horizon than when above our heads; near the horizon the moon is more dim, we therefore by analogy suppose her more remote; but her visual diameter being really the same, we therefore are persuaded that her disk is broader.

Hitherto we have considered sight in reference to vision with a single eye; but habitually we employ both eyes; and it is interesting to inquire what are the conditions which render vision under these circumstances single or double.

It is to be borne in mind that the centre of the retina, from whatever cause it may proceed, furnishes the most distinct vision. Hence in looking at a point of an object, we invariably direct the axis of the eye towards it; and when we look with one eye at a succession of objects placed *in a line directly* before us, but at different distances, the optic axes are seen to incline inwards when we regard the nearest object, and to increase their direction outwards as we view those which are more remote.

Now when we look with both eyes at any one of such a series of objects, that one appears single, the rest appear double. This familiar but remarkable phenomenon has given rise to the hypothesis that there are corresponding points in either retina; it is supposed that when an object is delineated upon those points of the two retinæ which are naturally associated, it appears single, and double under other circumstances. But it seems unnecessary to resort to this explanation of the fact. It has been already shown that objects are seen in a definite direction; when therefore it happens that the visual direction of an object is the same or nearly the same for both eyes, that object appears single; when different, the object appears double. In both cases two objects are seen: but in single vision they are seen in the same place, and therefore necessarily appear to form but one: the images coincide, and are therefore essentially indistinguishable.

It is easy through another simple artifice to render vision double. By pressure with the finger we may raise or depress

one eyeball,—when the object seen by that eye appears to shift its place, as the position of the organ is varied. The effect, which is thus produced at will in an experiment, sometimes occurs as the result of disease. M. Magendie mentions the case of a gentleman in whom, from palsy of the third nerve, the left eye is permanently drawn outwards; the consequence of which, he observes, is, that with that eye the patient sees objects *in their wrong place*, "déplacés de vingt á vingt cinq dégrés *á droite de leur position.*" The case is curious, but not without its parallel; and the account of the result of the displacement of the eye is incorrect. It is not true that the object is seen by the averted eye *out of its true position;* the proof of which is, that an eye thus affected, or similarly pushed aside for experiment's sake, will take as true an aim as before, or look along a line as justly towards a remote object. The object is seen apparently in two places, yet both eyes see truly. This paradoxical circumstance renders evident one of the most curious provisions in our frame, namely, the extreme nicety with which the two eyes are collocated, so that their impressions may exactly tally.

The convergence of the optic axes has to do in a certain degree with our appreciation of distance and real magnitude. When, indeed, objects are placed at such a distance that in regarding them the optic axes remain parallel, our notions upon these points are entirely derived in the ways already explained. But when they are situated nearer, the sensation attending each degree of inclination of the optic axes enters as an important element into our estimate. Mr. Wheatstone has shown, in a paper he is about to publish, that if by artificial means the usual relations which subsist between the degree of inclination of the optic axes and the visual angle which the object subtends on the retina be disturbed, some extraordinary illusions may be produced. Thus the magnitude of the image remaining constant on the retina, its apparent size and distance may be made to vary with every alteration of the angular inclination of the optic axes. The author also proves, that the adaptation of the eye to distinct vision exercises no modifying influence on these perceptions; and, contrary to the opinions of Dr. Wells and other eminent optical writers, that there exists no necessary connection between this adaptation and the convergence of the axes.

One of the most remarkable results of Mr. Wheatstone's investigations respecting binocular vision is the following. A solid object being placed so as to be regarded by both eyes, projects a different perspective figure on each retina; now if these two perspectives be accurately copied on paper, and presented one to each eye so as to fall on corresponding parts, the original solid figure will be apparently reproduced in such a manner that no effort of the imagination can make it appear as a representation on a plane surface. This and numerous other experiments explain the cause of the inadequacy of painting to represent the relief of objects, and indicate a means of representing external nature with more truth and fidelity than have yet been obtained. It would require too much space to enter upon the physiological views to which these experiments have led their author.

For perfect vision with the human eye, it seems requisite that the rays of light should undergo no reflection after reaching the retina. To provide for this object, the delicate membrane called the chorioïd, which immediately contains the retina, secretes in the human eye a black mucus called the pigmentum nigrum, which has the effect of absorbing the rays of light which have once reached the retina. Those in whom this black pigment is wanting have a weak sight, and only see distinctly in an obscure light. We may suppose the retina in such cases liable to be dazzled by the reflection of part of the light from the vascular chorioïd. On the other hand there are animals, which habitually seek their prey in the dusk; in these and in several instances where the final cause of the peculiarity of structure is not equally obvious, the back part of the chorioïd is covered with a membrane termed the tapetum lucidum, which presents a brilliant reflecting surface. The lustre of the eyes of cats in an obscure place results from this cause. It is supposed that the double impression of a low degree of light upon the retina may be equivalent to the single impingement of brighter light. M. Magendie ingeniously compares with this disposition of parts a structure observed by himself in the eyes of birds remarkable for their acute vision. In the eagle, the retina lies in numerous folds, so that we may suppose it several times perforated by the rays of light.

The eye of the Albino is remarkable for its want of pigmen-

tum nigrum, in consequence of which the pupil and the iris are coloured of different shades of red. In such persons vision is weak in the ordinary light of day, and distinct only in a darkened room or at twilight. The eyes of Albinoes are likewise observed to be in perpetual motion, unconsciously oscillating from side to side, even when their sight is most steadily bent upon an object. There can be little doubt that this provision is intended to save the unprotected retina, by preventing a continued impression of undue intensity upon one point. Other people use one part of the retina for perfect vision, and direct it successively towards the different points of an object while examining it: the Albino uses several, continually alternating from one to the other. The motion is unattended with any apparent change of place in the object (such as that adverted to when the eye is pushed or drawn aside), upon the same principle as when for experiment's sake we intentionally roll the eye from side to side: the scene before us in either case remains visibly stationary, because the parts of the retina upon which each point of an object is successively delineated, are in their turn brought opposite to the same point in space.

The principal use of the iris appears to be, to equalize the quantity of light admitted within the eye under different circumstances. It is well known that the aperture of the iris, or the pupil, is diminished when light is more intense, and enlarges under a more obscure light. What principally deserves attention in this phenomenon, is the mechanism through which a change in the diameter of the pupil is produced.

The most ready manner of accounting for the alteration of the size of the pupil is to suppose the substance which forms the unattached margin of the iris irritable. In many instances the iris distinctly consists of two portions, which appear from their colour to be differently organized — of an outer broader part, and an inner narrow ring. In birds especially, in which the pupil is as mobile as their vision is perfect, the inner ring of the iris generally presents a hue totally different from the outer, and beginning at an abrupt line. In a parrot belonging to Mr. Hawes, of which I do not know the species, the inner ring is grey or slate-coloured, the outer ring yellow or orange. If the eye of this animal is attentively watched, the grey inner ring of the iris may be observed, when the pupil contracts, to

become sensibly narrower, as if it is the part that acts. I have not observed a similar change, however, in the iris of any other bird, though many have the iris similarly coloured.

Upon watching the eye of a cat or of a hawk, the contraction of the pupil appears often to be voluntary. When the eye of the animal is bent upon an object that excites its attention, yet which does not shift its position, the pupil may be seen to enlarge and to contract alternately. The animal is probably employed in examining the object under different lights by intentionally admitting more or fewer rays through the pupil.

Another remarkable circumstance concurs with the preceding in establishing a resemblance between the action of the iris and that of voluntary muscles. The iris receives nerves from two sources, from the sentient part of the fifth, and from the third: the main part of the latter is distributed as a voluntary nerve to the muscles of the eye. Now if the head of a pigeon is cut off, and, instantly after, the upper part of the cranium is removed, and the entire brain be taken out, on pinching the portion of the third nerve which remains attached to the eye, I observed that the pupil is contracted suddenly, just as the biceps flexor cubiti acts in an animal recently killed, when the nerve which supplies that muscle is pinched. A similar injury to the fifth nerve produces no visible effect.

If the third nerve is divided in the cranial cavity, while the animal is alive, the pupil immediately dilates to the utmost, and remains afterwards immoveable, the iris being seemingly paralysed. When again the third nerve is pinched in the cranial cavity of a young cat instantly after death, the iris will occasionally act as in the pigeon. In either case the exposure of the nerve must be very promptly executed, or the effect described does not happen.

I have already mentioned the curious changes which M. Magendie observed to ensue gradually in the eyes of rabbits after the division of the fifth nerve; but another remarkable effect followed instantaneously: the pupil became diminished to a point, and the eye was apparently blind. Blindness, however, had not appeared to ensue in pigeons in which I had before this made the division of the fifth nerve, and I have subsequently ascertained that the division of the fifth nerve in the cranial cavity of a cat produces no such effect; and M. Magendie has likewise since found, that if a bright light be con-

centrated with a lens upon the eye of the rabbit after the same experiment, the retina is evidently sensible to the impression. But the contraction of the pupil in this experiment remains unexplained;—a singular anomaly, placed perhaps in a still stronger light by the following experiment, which I have repeated several times. A young rabbit being killed, the upper part of the cranium was immediately removed, together with the cerebrum. The optic nerve thus exposed was pricked, and then divided; no movement of the iris ensued: the third nerve was pricked and then divided; the iris exhibited no change: the fifth nerve was then slightly compressed, when the pupil became contracted, not suddenly, but slowly and gradually, and then slowly dilated again: upon now dividing the fifth, the pupil became contracted to the utmost, but in a gradual manner, although more promptly than when compressed only, and remained in this state. It is difficult to explain this singular phenomenon. But it should be mentioned in connection with it, that in the cat and pigeon, in which the iris is paralysed by the division of the third nerve, and the pupil remains permanently dilated afterwards, the pupil dilates likewise in death. In the rabbit, on the contrary, the pupil contracts as soon as life is entirely extinguished.

It remains uncertain what properties the human iris is endowed with. It is probable that its inner unattached edge is capable of voluntary contraction: but being accustomed to employ it on two occasions alone (when the light thrown on objects or their distance varies), we lose part of our original control over it. Such appears to be the condition of the muscles of the soft palate, which most persons are capable of moving in one or two combined actions only; but they are not the less under the influence of the will; and some persons are found, according to M. Magendie, who can move them separately at pleasure.

If light be too intense, the eye is dazzled, and objects are no longer distinguished: if the quantity of light be very inconsiderable, no adequate impression is made upon the retina, and vision does not take place. If again we enter suddenly an obscure chamber not absolutely dark out of bright daylight, for a few seconds we discern nothing; but the eye quickly accommodates itself to the obscurer light, and vision is restored.

Under any advantage of light it appears that objects are only

perfectly seen when within a certain range of distance. The image of an object upon the retina [as upon a mirror] is diminished in proportion as its distance is increased; and when the space the image occupies is reduced to less than a certain dimension, it wholly ceases to produce sensation. This remark, it will be seen, bears upon an expression that has been employed in the preceding pages, and which, though it is convenient to retain it, must be taken with some modification of its meaning. The cone of rays which enters the pupil from any visible point of an object is said to converge to a focal point upon the retina; it is obvious, that such a focal point is different from a point in the mathematical sense of the word; it signifies only a very small circle.

But there is another cause, why the range of perfect vision has its limits, which has been already adverted to. It appears by the phenomena of myopic and presbyopic eyes, that a very nice arrangement of the rays of light upon the retina is necessary for distinct vision; it is not therefore wonderful that we cannot see perfectly at all distances; but on the contrary it ought rather to excite our admiration, that we are able to see objects with any degree of distinctness at more distances than one. For when we consider how different the angles must be at which the marginal rays of each cone reach the pupil from objects of different remoteness, it is natural to expect that the focal length of the eye adapted to any one case will be entirely unfit for others. Nevertheless we are not conscious of having to make an effort to change the refractive power of the eye, at the time when we direct our attention from a near object to one more distant.

A simple experiment, however, serves at once to prove, that when the eye is adapted to seeing objects distinctly at one distance, it is not adapted to seeing objects with equal distinctness at another; and that we possess a voluntary power of altering the focal length of the eye.

If a clear straight line is drawn with a pen upon a plane white surface from a foot to three feet in length, and the eye is placed just above the level of the white surface, and is directed along the black line, the latter appears distinct at one point only, on either side of which it appears confused, and spread over a widening space. If the eye is fixed upon a

point nearer than that first looked at, but within the limits of distinct vision, the near point becomes clearly defined, and the remote point confused.

In Dr. Young's optometer such a single line is seen through several narrow slits in a thin brass plate, two or more of which correspond with the aperture of the pupil. Hence it happens, that except at the point to which the eye is adjusted, the line appears double or triple: or the separate lines are seen to cross at the point at which vision is distinct; and the crossing of the lines may be made to appear more or less remote by directing the attention successively to different points of the surface. By means of a convergent lens, the effect of unlimited distance is given to the length of a few inches upon the optometer, while a graduated scale shows the true distance at which vision is distinct.

At eighteen or nineteen years of age, a good eye should be capable of adjusting itself to objects situated at any point between five or six inches from the eye and infinite distance, or even of bringing to a focal point upon the retina convergent rays. As life advances, the range of the adjusting power of the eye is continually diminished by an increasing inability to distinguish *nearer objects.* Between fifty and sixty, the refractive power of an eye originally perfect is qualified to bring to a focus parallel rays only, and the power of adjustment is wholly lost. A myopic eye does not, as it is usually supposed, acquire a long sight in the advance of life; it possesses at first a certain power of adjustment, as for instance, between four and twelve inches; and when the power of adaptation is lost, its vision, like that of an eye originally good, continues perfect at the *remotest point* to which its powers of adjustment originally extended.

The mechanism by which the eye alters its focal length remains in obscurity, notwithstanding the numerous attempts that have been made to explain it.

An experiment made by Dr. Young, contravenes the supposition that the change produced for this purpose consists in an alteration of the form of the cornea. A convex lens fixed in a socket, which contained water, and the edges of which were secured with wax, was applied to the eye, so that the cornea entered half way into the socket, and was everywhere in contact

with the water: the eye immediately became presbyopic; but upon the addition of another convex lens to make up for the loss of the refractive effect of the aqueous humour, vision was restored to its natural state, and the eye regained the power of adjustment*.

Other experiments, made by Dr. Young, set aside the supposition that a change takes place in the length of the axis of the eye, to fit it for vision at different distances;—if experiments are indeed necessary to disprove the application to this delicate organ of any considerable pressure, of which we have no consciousness at the time when upon this hypothesis it should take place.

Dr. Young himself concludes that the means of adjustment consist in a change of form in the crystalline, the fibres of which he describes, and which he supposes to be irritable. But it does not appear from direct experiment that the crystalline possesses irritability; and if a conclusion may be drawn from a single observation upon a point so delicate, the instance of Henry Miles, recorded by Sir Everard Home, will seem to prove that the eye may retain its power of adjustment after the removal of this part†.

The only evident change in the eye, when adjusting its focal length to different distances, is an alteration in the diameter of the pupil. The pupil enlarges when a distant object is seen, and diminishes when we look at a nearer point. Upon a superficial analogy we might conclude, that these changes are sufficient to produce the requisite alterations of the focal length of the eye: for by viewing objects through a series of pinholes in a card, the largest smaller than the aperture of the pupil and each of the rest in succession smaller than the last, the eye is rendered capable of seeing distinctly at the distance of four, of three, and even of two inches. When, however, the correctness of this hypothetical explanation is put to the test of direct experiment, the explanation proves to be erroneous.

In investigating the point under consideration, I availed myself of the assistance of Mr. Robinson, of Devonshire Street,

* Phil. Trans. vol. xci, p. 58.

† Phil. Trans. vol. xcii, p. 8.

a very ingenious artist, who makes the optometer contrived by Dr. Young, and who is conversant with the use of that instrument.

A room was darkened by half closing the shutters, and I attentively observed the state of the pupil, when Mr. Robinson directed his eye to a definite point upon the optometer: the pupil was of course considerably dilated: the shutters being then opened, the pupil instantly contracted, but the point upon the optometer at which the lines crossed did not appear to the observer to shift its place.

When by some practice I had accustomed my own eye to the use of the optometer, I compared its range in the brightest and in the obscurest light in which the lines were visible, and observed no apparent difference in the two cases. Mr. Robinson made a similar observation. Either of these experiments prove that the change in the size of the pupil is not the means by which the adjustment of the eye to distances is effected. But an additional fact may be mentioned. In an old lady of sixty-seven, whose sight in early life was remarkably good, but whose eyes can now only bring to a focus parallel rays, the pupil retains its mobility perfectly under variations of light; and even sensibly moves upon her making ineffectual attempts to read without spectacles a page held at different distances from her.

It deserves remark, that after the eye has had some practice in accommodating itself to exact vision at different distances, it is easy when an object, as for instance a screen, is held at the distance of six or seven inches, and has been for a few seconds distinctly seen, to adjust at pleasure the focal length of the eye for vision at a remoter point: under these circumstances the object held before the eye becomes confusedly seen; the optic axes diverge, and the pupil dilates. In a similar way the eye may be adjusted at pleasure to a shorter distance, at which no visible object is situated: thus a power appears to be acquired of voluntarily influencing the action of the iris.

I have already observed that one part of the retina appears habitually used for accurate vision: to illustrate this subject further, I subjoin the following extract from a paper of Dr. Young's in the Philosophical Transactions.

"The visual axis (observes Dr. Young) being fixed in any direction, I can at the same time see a luminous object placed laterally at a considerable distance from it; but in various directions the angle is very different. Upwards it extends to 50 degrees, inwards to 60, downwards to 70, and outwards to 90 degrees. These internal limits of the field of view nearly correspond with the external limits formed by the different parts of the face, when the eye is directed forwards and somewhat downwards, which is its most natural position; although the internal limits are a little more extensive than the external; and both are well calculated for enabling us to perceive the most readily such objects as are likely to concern us. Dr. Wollaston's eye has a larger field of view, both vertically and horizontally, but nearly in the same proportions, except that it extends further upwards. It is well known that the retina advances further forwards towards the internal angle of the eye than towards the external angle; but upwards and downwards its extent is nearly equal, and is indeed every way greater than the limits of the field of view, even if allowance is made for the refraction of the cornea only. The sensible portion seems to coincide more nearly with the painted chorioïd of quadrupeds; but the whole extent of perfect vision is little more than ten degrees; or more strictly speaking, the imperfection begins within a degree or two of the visual axis, and at the distance of five or six degrees becomes nearly stationary, until at a still greater distance vision is wholly extinguished. The imperfection is partly owing to the unavoidable aberration of oblique rays, but principally to the insensibility of the retina; for if the image of the sun itself be received on a part of the retina remote from the axis, the impression will not be sufficiently strong to form a permanent spectrum, although an object of very moderate brightness will produce this effect when directly viewed. The motion of the eye has a range of about 55 degrees in every direction, so that the field of perfect vision, in succession, is by this motion extended to 110 degrees*."

Mariotte discovered the curious fact, that there is a certain part of the retina insensible to the ordinary impressions of light. The most ready way of making the experiment which proves this, is to look steadfastly with one eye, the other being closed, at a mark on a sheet of white paper, placed at the ordinary

* Phil. Trans. vol. xci, p. 46.

reading distance from the eye; and whilst the eye thus remains stationary, to move a coloured wafer along the surface of the paper on the external side of, and on the same horizontal line with the mark. At a certain point in this line, the wafer will completely disappear; but it may be rendered again visible, by moving it either farther from or nearer to the fixed mark. This insensible part may be shown to correspond with the place at which the optic nerve enters. This circumstance induced Mariotte to consider the chorioïd as the seat of vision rather than the retina; for, argues he, here is no deficiency of that nervous matter of which the retina is the expansion, but the chorioïd is wanting. The following experiment of Purkinjè's will show the erroneousness of this conclusion, which has not wanted supporters among modern physiologists. By repeating the above experiment, substituting the flame of a candle for the wafer, he has proved, that though no image of the object is formed at this part, it is still not insensible to light, for a diffused reddish light appears to occupy the place of the flame. The optic nerve is not insensible, as Mariotte's hypothesis supposes; but objects are not seen by this part, in consequence of their image falling on the projection of the central artery, which here emerges from and traverses the nerve. The red nimbus results from the passage of light through this blood-vessel, the irregularity and semi-transparency of which prevents it from transmitting the image.

Dr. Wollaston described a partial and temporary insensibility of the retina in both eyes which twice occurred to himself, and which has directed attention to similar cases. The following are Dr. Wollaston's words.

"It is now more than twenty years since I was first affected with the peculiar state of vision to which I allude, in consequence of violent exercise I had taken for two or three days before. I suddenly found that I could see but half the face of a man whom I met; and it was the same with respect to every object I looked at. In attempting to read the name JOHNSON over a door, I saw only SON; the commencement of the name being wholly obliterated to my view. In this instance the loss of sight was toward my left, and was the same whether I looked with the right eye or the left. This blindness was not so complete as to amount to absolute blackness, but was a shaded darkness without definite outline. The complaint was of short duration, and in about a quarter of an hour might be said

to be wholly gone, having receded with a gradual motion from the centre of vision obliquely upwards toward the left.

"Since this defect arose from over-fatigue, a cause common to many other nervous affections, I saw no reason to apprehend any return of it, and it passed away without need of remedy, without any further explanation, and without my drawing any useful inference from it.

"It is now about fifteen months since a similar affection occurred again to myself, without my being able to assign any cause whatever, or to connect it with any previous or subsequent indisposition. The blindness was first observed, as before, in looking at the face of a person I met, whose *left* eye was to my sight obliterated. My blindness was in this instance the reverse of the former, being to *my right* (instead of the left) of the spot to which my eyes were directed; so that I have no reason to suppose it in any manner connected with the former affection.

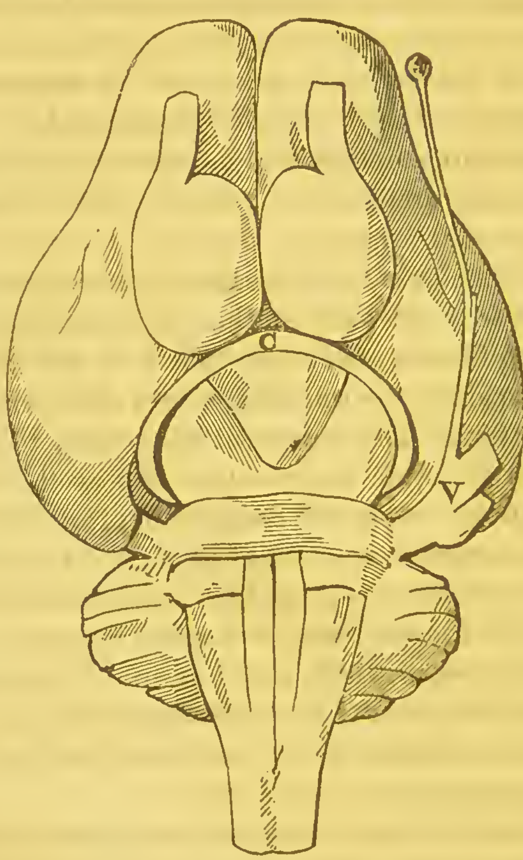
"The new punctum cæcum was situated alike in both eyes, when at an angle of about three degrees from the centre: for when any object was viewed at the distance of about five yards, the point not seen was about ten inches distant from the point actually looked at.

"On this occasion the affection, after having lasted with little alteration for about twenty minutes, was removed suddenly and entirely by the excitement of agreeable news respecting the safe arrival of a friend from a very hazardous enterprise."

Dr. Wollaston was led to infer from the symptoms which have been described, a peculiarity of structure in the commissure of the optic nerves, the existence of which has been confirmed by anatomical examination. It has been already mentioned, that the outer fibrils of the tractus opticus of one side are continued to form the outer part of the optic nerve of the same side, and that the fibrils next in order pass over to the inner and central part of the opposite nerve: thus the parts of the two retinæ, on which the same part of an object is delineated, are probably supplied from one nerve.

In the plate which I have given in a former section of the origins of the cerebral nerves, I have delineated the structure of the commissure of the tractus optici. Not the least curious part in it, is its containing fasciculi which do not reach either eye, but pass from one thalamus to the opposite. I introduce

in the present section, having omitted it in the preceding, a figure of the brain of the mole, which explains the nature of these fasciculi. In the mole, the optic nerve, with the third nerve, the fourth, and sixth, are entirely wanting. The little rudimental eye is probably an organ of touch alone: it is supplied by a branch of the fifth: the letter V in the figure below is placed on the fifth nerve. The letter C represents commissural fasciculi, which correspond with the posterior fasciculi above adverted to, in the commissure of the optic tracts in man. Traced in their retrograde course, these fasciculi pass as tractus optici to thalami, in this instance miscalled thalami nervorum opticorum. Or the thalami nervorum opticorum are thus shown to be of much less importance as matrices of the optic nerves, than as cerebral organs, which originate masses of divergent fasciculi in the brain.



The eyes of different animals vary remarkably in their capability of being directed at the same time to the same object. In some again a connection exists between the two optic nerves;

in others the optic nerves are separate, from their origin to their termination. It is found that the separateness or greater or less union of the optic nerves bears a constant relation to the position of the two eyes, and to their consequent inability or greater or less ability to see the same objects at the same time. It has been observed in birds, that the degree of blindness, which is produced by opacity of the cornea, is alone sufficient in the space of three weeks to produce wasting and discoloration of the optic nerve, which extends to the tubercle of the opposite side; and conversely, that if the optic tubercle be injured on one side, blindness of the opposite eye immediately ensues. In human beings, atrophy of the optic nerve follows blindness very slowly, and the same alteration is seldom continued beyond the commissure. Nevertheless I have witnessed in one instance a discoloration of the optic nerve on one side joined with a similar appearance for a short extent upon the opposite tractus; but the intermediate portion of the commissure was white, and the history of the case was unknown. Sometimes the atrophy extends instead to the tractus of the same side.

In the preceding details the movements of the eyeball have been occasionally referred to: we may now examine the contrivances provided for this purpose, and the nature of the external parts intended for the protection of the organ of vision.

The delicate mechanism of the eye is inclosed in a spherical case of strong fibrous membrane, which is called the sclerotic: the posterior part of the sclerotic is .044 of an inch in thickness, the anterior .022. The parts within adhere to it only at the point where the optic nerve enters, and at the margin of the opening in front, where the cornea is let in. The line of adhesion here, however, is only .02 of an inch: it is called the ciliary ligament: it unites something less than the middle third of the ciliary body to the sclerotic, with great firmness.

The optic nerve, of which about an inch is interposed between the foramen opticum and the eyeball, contributes, through the strength and thickness of its outer tissue, to hold the eye forward, towards the front of the orbit.

The intervals between the different parts contained in the orbit are filled with adipose substance, in which the globe of the eye rolls, as in a well-oiled socket.

Six muscles are inserted into the sclerotic, of which four are termed recti, and two obliqui.

The recti are thin flat muscles which rise from the margin of the foramen opticum, and extend, one over the upper part, one upon the outside, a third upon the inside of the eyeball, and a fourth below it, to be inserted each by a broad thin tendon into the sclerotic at about four lines from the edge of the cornea.

The four recti are distinguished individually by the names of, superior, inferior, internus, and externus, with which the terms, attollens, deprimens, adducens, and abducens, are used synonymously. By careful dissection a layer of membrane may be separated from the part of the sclerotic between the insertion of the recti and the cornea. This membrane is termed the tunica albuginea, and is considered to be the aponeurosis of the recti muscles.

It is easy to understand that these muscles acting singly will direct the eye to four equidistant points in a circle, and acting in concert may turn the axis of the eye towards all the intermediate points; and it is equally obvious that they must exert a constant effort to retract the eye, against which the elasticity of the optic nerve, and of the adipose substance in the orbit, would make very inadequate resistance.

The two remaining muscles of the six appear intended to counteract the effect last adverted to.

The obliquus superior or trochlearis rises from the upper and inner part of the edge of the foramen opticum, and advances obliquely forwards and inwards towards the margin of the orbit, where a loop of membrane is attached, through which its tendon passes; the tendon is subsequently reflected downwards, backwards, and outwards, to be inserted into the upper part of the eyeball behind its vertical axis.

The obliquus inferior oculi rises from the nasal process of the superior maxillary bone, and passes obliquely outwards and backwards below the eyeball, to be inserted into the sclerotic within the rectus externus, and behind the transverse axis of the eye.

The action of the obliqui is involved in some obscurity: there can indeed be no doubt respecting their principal use; by drawing the eye forwards they prevent that constant retraction which would otherwise be produced by the recti. But individually they are calculated to give each its specific direc-

tion to the eye: the obliquus superior points the optic axis downwards and outwards; the obliquus inferior, on the other hand, directs the eye upwards and outwards.

What renders this question still more intricate, is, that three nerves are employed to supply the six muscles that have been described. The fourth nerve supplies the obliquus superior, the sixth supplies the rectus externus, and the third supplies the remaining muscles.

It is remarkable again, that of the six muscles of the eye-ball, three turn the optic axis directly or obliquely outward, and that each of these three muscles is supplied by a different nerve; two indeed have an entire nerve exclusively distributed to each of them.

The intricacy of the muscular nerves of the eye admits, however, of a conjectural explanation. We may remark, that their distribution is not such as to allow of our opposing the recti to the obliqui as classes of opposite endowments, such as instinctive and voluntary, or the like: in following this hypothesis we are stopped by the fact, that the third nerve supplies half, or the greater part of each class. But from the close anatomical relation between the origins of the third nerve and of the fourth, we may conclude *their* functions to be not materially different; whereas the sixth nerve, rising from a remote point, seems distinguished essentially from both the others.

It appears to be a principle universally observed in the construction of the nervous system, that nerves of motion rise near the origin of those sentient nerves, through which the actions they control are habitually guided or called into play.

This principle, as I have already shown, is remarkably exemplified in all the spinal nerves; and in the distribution of the fifth and seventh cerebral nerves; and the origin of the third and fourth nerves is perhaps sufficiently near that of the optic nerve to bring them both under the same law. Now when we trace to its origin the sixth nerve, we find it passing to the back part of the medulla oblongata, so as to rise near the fifth and the seventh; in other words, it rises near those nerves which comprehend within their functions the sensibility of the surface of the eye, an influence over the secretion of the lachrymal gland, and the sense of hearing. When again we examine the distribution of the sixth nerve, we find it forming the sole supply of a muscle which has a remarkable consent

with the three offices alluded to. The rectus externus or abducens oculi, which it supplies, directs the axis of the eye outwards. And we may remark, 1, that when the optic axis is directed outwards, the surface of the eye is carried towards the orifices of the ducts of the lachrymal gland: 2, that the reversion of the eye for vision is commonly suggested by impressions upon the organ of hearing: and, 3, as an instance of the consent between the common feeling of the eye and the action of the abductor, that when an animal is destroyed by pithing, if while imperfect life yet remains in the head the eyelids be rendered incapable of closing by the division of the portio dura, and the surface of the eye be then touched, the motion of the eye to avoid the offending substance is in a direction outwards.

We may suppose then that the third and fourth nerves are of one and the same power; and we may remark that three of the recti, the upper, lower, and inner, with the two oblique, which these nerves supply, are sufficient for determining the direction of the eyeball in connection with vision. For the two oblique are capable, not merely of keeping the eye forward in the orbit, but their combined action will direct its axis outwards, and the three recti can turn its axis in every other direction. There remains then apart, or superadded, the abductor muscle, with the sixth nerve that supplies it. This apparatus may serve, as I have just explained, on the one hand to place the eye in relation with the lachrymal gland, and the senses of hearing and of feeling; but besides—and this probably is a more important suggestion than those which have been already advanced — the two abductor muscles, with their separate nerves, may have the office of giving divergence to the optic axes, or of maintaining their parallelism in ordinary vision.

When the eyelids are kept shut, the eyes are often in motion. "Inter somnum quietum atque placidum (observes Soemmering in his Icones Oculi Humani), bulbus oculi, ut in ipsis somnolentis videre licet, paullo plus *sursum* trahitur." In some instances this elevation of the axis of the eye during sleep is very considerable, in others it is very slight.

Squinting consists in a want of consent between the muscles of the two eyes, through which defect the optic axes are habitually directed towards different points. The inclination of one eye inwards may be so great as to exclude it from the vision of

objects towards which the other is turned, or may be so slight as to allow of the distorted eye taking in part of the same field of vision with its fellow. In either case it appears that those who squint, habitually neglect the impressions upon the distorted eye, and see with but one.

The cause of squinting is obscure: for though it frequently happens that the eye which squints has an imperfect vision, so as to favour the supposition that it is instinctively averted in order to prevent the perception of objects becoming confused; yet in other cases, vision with either eye is equally good, and the patient can at will employ either singly, but cannot prevent the other from turning away from the object of vision.

Perhaps in cases of the latter description the original adjustment of the two eyes is not true; so that if both were directed towards the same object, it might necessarily appear double, upon the same principle as in the case recently quoted from M. Magendie's works.

The parts employed for the protection of the eye are, the eyelids with their muscles, the tunica conjunctiva, and the lachrymal gland.

The eyelids are two folds of skin, to which shape and firmness are given by two slips of cartilage termed the tarsi. Upon the surface at which the eyelids meet, the skin is gradually transmuted into a mucous membrane termed the conjunctiva, which lines the tarsal cartilages, and is reflected from the inner surface of the eyelids upon the sclerotic coat, to cover the front of the eye, the tunica albuginea, and the cornea. The tarsal cartilages have a membranous joint at either corner, from which a ligament extends to the adjoining bone: the ligament on the inside is well defined, and of a bright silvery colour, and is called the tendo oculi; it extends to the nasal process of the superior maxillary bone: the external ligament is broader and of a membranous character; it extends to the frontal process of the malar bone.

The opposed edges of the tarsal cartilages are so grooved and sloped internally, as to form when they meet a channel, which is closed at the back part by the eyeball. The external edge of this groove is guarded by the strong hairs which form the eye-lashes, and upon its inner edge from thirty to forty thin white ducts open, which are termed glands of Meibomeus; they are filled with a white sebaceous or albuminous material.

At the inner canthus of the eye the tunica conjunctiva is reflected over a fleshy fold termed the caruncula lachrymalis. The liquid which lubricates the surface of the eye appears raised by this fold of membrane to the apertures of the puncta lachrymalia, as the two capillary tubes are termed, which absorb the liquid from the surface of the eye; they terminate in an oval bag, termed the lachrymal sac, which is lodged in a fossa common to the os unguis and superior maxillary bone, and transmits the tears onward towards the nose.

The tears are a salt transparent liquid, a hundredth part only of which consists of saline ingredients. Soda and muriate of soda, phosphate of lime, and phosphate of soda, with mucus and water, are the component parts of the tears, according to Fourcroy and Vauquelin. The tears are secreted by the lachrymal gland, a flattened circular body, in structure and appearance resembling a salivary gland, which is placed at the outer and upper part of the orbit: its five or six small ducts open at the neighbouring angle of reflection of the tunica conjunctiva from the upper palpebra upon the eyeball.

The lachrymal gland is supplied with two nerves from the first division of the fifth: its secretion is remarkably under the influence of the mind. Yet the surface of the eye does not seem less moist than usual when the fifth nerve has been divided, and it is questionable whether the liquid with which it is generally lubricated be derived from the lachrymal gland or from its mucous covering. The remarkable effect of dividing the fifth nerve upon the nutrition of the eye has been already described: it deserves remark, that the eye is rendered insensible to common stimuli by this operation. Diluted liquor ammoniæ applied to the eye in this state produces no inflammation of its surface, — a phenomenon extremely curious, when viewed in connection with the fact, that the operation itself produces a violent inflammation of the tunica conjunctiva in twenty-four hours.

When the optic axis is directed forwards, the eyelids meet at the lower margin of the cornea. The lower eyelid has little motion; the upper eyelid alone is concerned in the ordinary opening and shutting of the palpebræ.

The muscle which raises the upper eyelid is termed the levator palpebræ superioris; it rises from the margin of the foramen opticum immediately above the rectus superior oculi, and is

inserted into the upper tarsal cartilage: it is supplied by the third nerve.

The muscle which closes the eyelids is called the orbicularis palpebrarum; it is disposed for some breadth beneath the skin of the eyelids in concentric fasciculi. This muscle is supplied by the fifth nerve and by the portio dura of the seventh, and is paralyzed by the division of the latter. The fifth nerve and the seventh rise together: the fifth imparts sensibility to the surface of the eye, to the eyelids and eyelashes; and the least irritation of these parts calls into action the orbicularis palpebrarum, which receives its stimulus through the portio dura of the seventh. If the hand is moved rapidly before the eye at three inches distance from its surface, we are scarcely tempted to close the eyelids; but if it approach so near as sensibly to affect the eyelashes by the displacement of the air, though we are conscious that it threatens no injury, we find it scarcely possible to refrain from winking. The consent between the fifth and the seventh nerve in this instance seems as close as that between the second and the third, or as the connection between a vivid impression upon the retina and the contraction of the pupil.

SECTION II.

Of the Organ of Hearing.

The physical impressions upon the organ of hearing which produce sensations of sound, consist in impulses regularly recurring within certain limits of frequency. In all ordinary cases of the production of sound, these impulses originate from vibrating bodies, and are communicated to the organ of hearing by means of undulations excited in the air.

The limits between which regularly recurring impulses are perceptible as sounds have been generally stated at 30 in a second on the one extreme, and from 8000 to 12000 on the other: but some recent investigations by Savart show, that acute sounds may be perceived resulting from 24000 impulses in a second, and that grave sounds may be appreciated arising from 7 or 8 impulses only. He has found such sounds in either

extreme capable of being rendered appreciable by the senses upon increasing their loudness. Dr. Wollaston conceived, from trials made with very acute sounds on a number of persons, that the limit of audition with regard to acuteness of sound is variable in different individuals: but Savart has shown, that these experiments only prove different degrees of sensibility in the individuals with respect to the intensity of sound, and that had the intensity of the sounds excited been greater, the limits of hearing might have been the same in all.

The length of the interval between two successive impulses, or, which is the same thing, the number of impulses in a given time (a second is the time generally assumed), constitutes the pitch or musical degree of the sound. Grave sounds are those in which the interval between the impulses is greater, and acute sounds those in which it is less: these are merely terms of comparison; and the same sound may be acute compared with one more grave, and grave compared with one more acute.

It does not appear that a continued series of isochronous impulses is necessary to constitute a comparable musical sound: *two successive* beats are sufficient to give rise to the sensation, and the pitch of the sound is solely determined by the duration of the interval between them. It follows, therefore, that in the most extreme limit of acute sound which has yet been determined, a sound is perceptible which lasts only the 24000th of a second.

A phenomenon analogous to the duration of luminous impressions on the retina has been observed with regard to sound; in a continuous series of isochronous impulses, a very considerable number may be intermitted without impairing in the slightest degree the apparent continuity of the sound.

These curious facts never could have been ascertained, had we been confined to experimenting on sounds produced by vibrating bodies: but a means of investigation originally proposed by Dr. Hooke, and successively improved by Robinson, Cagniard de Latour, and Savart, enables us to obtain every possible arrangement of impulses, and every requisite degree of intensity. By the extension of these means, our knowledge with regard to audition may be yet much extended.

The undulations arising from sonorous impulses are transmitted more rapidly through solids than through liquids, and

by liquids than by aëriform fluids. Sound travels through air with a velocity equal to 1142 feet per second; and it is calculated, that it would be transmitted through water with a velocity of 4900 feet, and through glass, iron, or deal wood, with a velocity of about 18000 feet per second.

Sound transmitted through a fluid spreads spherically in every direction. Hence it may be understood how sound, when moving through a fluid, is diminished in intensity (like light) in the ratio of the square of the distance. Sound likewise admits of being reflected like light: upon this principle depend the phenomena of echoes. Sound is deadened by passing from one medium to another. Sound perishes when no material substance fit for its transmission is present: a bell struck in an exhausted receiver is scarcely audible.

The essential part of the organ of hearing consists of a series of cavities, termed the labyrinth, hollowed in the petrous bone, within which is a membrane containing a liquid, in contact with which the portio mollis of the seventh nerve is expanded. The entire length of the labyrinth is .7 of an inch.

The labyrinth is divided into the vestibule, cochlea, and semicircular canals, a particular description of which would be superfluous, as the advantages resulting from their shape is unknown. But it deserves remark, that a provision is made for the free vibration of the fluid which they contain through two apertures leading into them, the fenestra rotunda and fenestra ovalis, that are closed by a membrane only.

As long as the labyrinth is perfect, no kind of obstruction of the external passages or removal of the external parts can absolutely extinguish hearing. In a total obstruction of the external passages, sounds may still be conveyed through the bones of the head to the auditory nerve; a tuning-fork, for instance, applied to the teeth, will still under these circumstances produce sensations of sound: thus in deafness a sufficient criterion is attainable to determine whether the cause is seated in the labyrinth or in the passages leading to it. In a total loss of the external parts, on the other hand, sound is capable of being communicated through the air to the membranes and liquid of the labyrinth, if these remain entire, nearly as perfectly, it should seem, as when the outer parts are complete *.

* It is to be observed, that the stapes is so strictly applied to the mem-

The chambers of the ear external to the labyrinth are the tympanum and meatus auditorius externus.

The tympanum is a narrow chamber, .6 of an inch in length, which opens forwards into the posterior fauces through the Eustachian tube, and is continued backwards into the cells of the mastoïd process. The membranes of the fenestra ovalis and fenestra rotunda alone prevent communication between the cavities of the tympanum and labyrinth. On the opposite side the membrana tympani is interposed between the tympanum and the meatus auditorius externus. A chain of bones, the malleus, the incus, the os orbiculare, and the stapes, extend from the membrana tympani to the membrana fenestræ ovalis; and four little muscles, the tensor tympani, the laxator tympani, the externus mallei, and the stapedius, by drawing upon the ossicula auditûs, give greater or less tension to the membranes which those bones unite.

The membrana tympani is very vascular, but presents a dry shining cuticular surface. It appears to contain fibres that converge towards its centre; which part is drawn inwards, and has attached to it the handle of the malleus. The diameter of the membrana tympani is .4 of an inch. It is worthy of remark, that the ossicula with their muscles are situated immediately within the *upper* half of the membrana tympani, or are placed at the upper part of the cavity of the tympanum: the practical application of this fact is the following.

The cavity of the tympanum communicates with the posterior fauces by means of a narrow canal called the Eustachian tube, which is partly cartilaginous, partly bony; the length of the entire tube is 1.1 inch, that of the bony part .4. Its office is the same as that of the hole in a kettledrum. Being narrow, however, it is liable to obstruction in many ways, of which the commonest is the swelling of the lining membrane from cold.

Now a common sort of deafness results from the obstruction of the Eustachian tube, which prevents the air in the tympanum from vibrating freely, and so interferes with the transmission of sound through it. An obstruction of the Eustachian tube is supposed to exist, when those sounds alone are heard that are conveyed through the bones of the head, at the same time

brana fenestræ ovalis, that the loss of this bone produces incurable deafness through the necessarily attendant injury of the labyrinth.

that the meatus auditorius externus is free, and the patient is unable to inflate the tympanum by impelling air into it from the fauces. Of course, if the cause of obstruction is a cold only, nothing is required to be done: but where the cause is permanent, such as closure of the orifice of the tube after the cicatrization of an ulcer, then means have to be adopted for restoring the air of the tympanum to free vibration, which consist in puncturing the membrane. This application of physiology was made by Sir Astley Cooper. The membrane is to be punctured at the lower part, to avoid the bones and the corda tympani nerve.

All that is known of the office of the membrana tympani is, that it opposes an obstacle to the entrance of foreign substances into the internal ear, while it presents no impediment to the transmission of sound.

The meatus auditorius externus, including the cartilaginous part, is an inch in length; it is curved in two senses like an italic *ſ*, its general direction is horizontally outward and backward: its entire length is an inch and a half; the length of the bony portion of the tube being half an inch. This canal is fenced with short strong hairs, and its surface secretes a peculiar substance termed cerumen, which is of an orange-yellow colour and bitter taste, consisting of albumen, an oil, colouring matter, soda, and phosphate of lime *. The cerumen is liable to collect in thick inspissated masses, sufficient to obstruct the passage of sound along the meatus auditorius externus.

The external ear is formed of an expansion of the cartilage, which forms the outer half of the external meatus: its several folds and margins are distinguished by separate names: the helix is the outer folded edge; the antihelix is the fold parallel to the former: the deep hollow below and before the antihelix is called the concha, the anterior edge of which is formed by the fold termed the tragus, the posterior edge by the antitragus. The attollens, the retrahentes, and the anterior auris, are muscles which carry the outward ear in the directions which their names specify. The helicis major and minor, the tragicus and the antitragicus, and the transversus auris, are thin muscular slips, which extend from one point to another of the external ear, and are calculated to expand the different hollows and

* Thomson's Chemistry, vol. iv, p. 513.

x 2

fossulæ into which the surface of the ear is thrown. Among savage tribes the outward ear is prominent, and moveable like the ears of animals; their hearing is more acute than that of civilized nations, and it is probable that the motions of the external ear assist them in discriminating the direction and nature of different sounds.

The portio mollis of the seventh nerve we may infer from its distribution to be the nerve of hearing. The portio dura of the seventh traverses a canal in the temporal bone: it is joined in its course by a branch from the second division of the fifth nerve, and from the united trunk filaments are given to the muscles within the tympanum. But the portio dura is a nerve of voluntary motion, and the second division of the fifth is a sentient nerve; thus the circuitous route of the portio dura and its junction with the Vidian nerve are explained. The division of the trunk of the fifth nerve in cats within the cranial cavity does not seemingly affect the acuteness of hearing on the same side. Of what use the branches derived from the otic ganglion, and from the tympanine branch of the glosso-pharyngeal nerve that are distributed in the ear, is at present matter of mere conjecture.

SECTION III.

Of the Sense of Smell.

Particles are continually flying off from the surfaces of bodies, or the air seems to dissolve minute portions of every substance with which it is in contact. Hence arise the virtues of salubrious situations, or the poisonous qualities of such as are noxious; the atmosphere becoming impregnated with the elements of the soil in proportions too minute to be detected except through their influence on the animal frame, into which they are introduced by the absorption of air that takes place in the lungs. The atmospheric solution of many substances is distinguishable by the sense of smell. The organ of this sense forms the commencement of the respiratory tube, so that each time we breathe, the olfacient qualities of surrounding substances are submitted to our senses.

The sense of smell is calculated to give warning of the vicinity of unwholesome objects, and to minister to the appetites;

or like the sense of hearing, it may be employed to furnish a succession of impressions that are merely grateful. The influence of this sense over the frame is very remarkable: one odour will instantly produce loathing, nausea, and vomiting; another, like the pleasant fragrance of the country on a spring morning, has a part in producing an exhilarating influence upon the mind.

The organ of smell is separated into two chambers, by a partition, which is seldom exactly in the median plane of the head. This partition consists of the nasal processes of the ethmoïd and sphenoïd bones, of the vomer, and of the cartilago septi narium. The floor of each chamber or nostril is formed by the superior maxillary and palate bones; the outer wall by the superior maxillary bone, the palate bone, the os unguis, the os planum, the cartilago nasi lateralis, and the cartilago alæ nasi. The floor of each nostril is horizontal and slightly hollowed; the septum is nearly vertical and plane: at the upper part is the narrow cribriform plate of the ethmoïd bone; upon the outside, the lower cornu of the ethmoïd bone and the inferior turbinated bone fall like curtains, leaving a passage towards the pharynx, the upper and outer part of which is divided into three channels. The frontal sinuses open through the anterior cells of the ethmoïd bone into the middle channel of the nostrils: the sphenoïd cells and the antrum of Highmore open through the posterior cells of the ethmoïd bone into the superior channel. The lachrymal duct opens into the inferior channel.

The thick and vascular mucous membrane, which invests this extensive surface of bone and cartilage, is termed the Schneiderian membrane. Over the whole of it are distributed branches of the fifth nerve; upon the fore part, a branch from the nasal portion of the first division of the fifth; upon the remaining surface, branches derived from the ganglion of Meckel. The distribution of the first nerve is more limited. The first nerve enlarges into an oval bulb, containing grey matter, upon the lamina cribrosa of the ethmoïd bone, which it perforates in numerous filaments, that are spread over the septum narium and the internal surface of the ethmoïd bone.

The simple contact of an atmosphere laden with odours is not sufficient to produce sensation in the nostrils. In order that smelling may take place, it is necessary that air impreg-

nated with the odour should be carried with some velocity against the surface of the Schneiderian membrane.

The upper part of the nostril appears to be the region to which the sense of smell is limited, or at which it is most exquisite. The apertures of the nostrils, and the inclination of the nose, are obviously adapted to direct the stream of air in that direction. Accordingly, when the nose has been destroyed by disease, smell is found to be greatly impaired or lost.

The first nerve is commonly believed to be that on which the sense of smelling depends. It may be observed that the nostrils are the only parts which distinguish odours, and although two nerves are distributed upon their sentient surface, one alone has its distribution confined to this organ. The acute sense of touch which the nostrils enjoy in addition seems a sufficient use for the remaining nerves which are spread upon the Schneiderian membrane: they are one and all derived from trunks, the other branches of which are nearly all nerves of common feeling.

M. Magendie tried the effects of the separate division of the first and fifth nerve in animals; and was led to entertain a doubt as to the received function of the first nerve. I think, however, that his experiments go no further than to show more precisely than was known before, how much of the impression received upon the nostrils belongs to smell properly so called, and how much to touch. It appears that upon the division of the first nerves the animal remains as sensible to the disagreeable impression of odours which act pungently, as before; a young dog thus mutilated appeared conscious of an unpleasant impression when ammonia, acetic acid, oil of lavender, or Dippel's oil, were held to its nose: on the other hand, after the division of the fifth, the first nerve remaining entire, an animal was not affected by the presence of the substances above mentioned. But M. Magendie mentions, that a dog, which survived the division of the fifth nerve for a considerable period, would at times, when food was offered to it rolled up in paper, unrol the paper, and expose and eat the food; although at other times he appeared to want the power of distinguishing by smelling the presence of objects placed near to it *.

Pungent odours seem to offend the nose upon the same principle that they irritate the surface of the eye, their acrid

* Magendie, Journal de Phys. Exper. vol. iv, p. 173.

impression, without their scent, being perceived, when the influence of the first nerve is artificially destroyed: such at least appears to be the inference justly deducible from the facts which M. Magendie has added to our knowledge upon this subject, and which leave the first pair of nerves in full possession of the faculty of smelling.

The following particulars of a case that occurred in the Middlesex Hospital, and which Dr. Watson communicated to me, would be decisive, if further evidence than that which I have advanced were wanting, to prove that smelling depends on the first nerve.

George Dickenson, aged twenty-five, received a violent blow across his forehead, which produced profuse bleeding from the nose, and deprived him permanently of the sense of smell: he used afterwards to feel a sensation as if his nostrils were stuffed. Three years after the accident he was seized with an epileptic fit, that was followed by drowsiness and insensibility, ending after three weeks in his death. Upon examining the head, there was found at the under surface of each of the anterior lobes of the brain, in the track of the olfactory nerves, an irregular depression or cavity nearly half an inch broad and one inch and an half long. The surface of the excavated part was of a yellowish colour, and had a semi-transparent gelatinous appearance. This appearance extended a little way into the substance of the brain. *The first pair of nerves for this part of their course were of the same colour;* there was no morbid appearance in the nostrils, and no disease of the corresponding parts of the dura mater. It may be presumed that the appearances described were the result of violence done to the brain by the blow received three years before the patient's death, and that the implication of the first pair of nerves in the lesion produced the loss of smell.

SECTION IV.

Of Taste.

The organ of taste is situated at the commencement of the digestive canal, and appears originally intended to provide us with the means of distinguishing wholesome food.

The seat of the sense of taste is the tongue and palate. The mucous membrane which covers the tongue is marked by a vast variety of little elevations. For an inch from its root the tongue is covered with mucous follicles: before these, fourteen or fifteen broad papillæ, termed papillæ conicæ, are found, that are contained in fossulæ, to which they adhere by their apices, while they present a broad and slightly cupped surface level with the dorsum of the tongue; about seven of these advance on either side from the centre to the edges of the tongue, the whole remaining surface of which is covered with oval papillæ that proceed in ranks parallel to the papillæ conicæ; these are termed papillæ conoïdeæ: at the edges of the tongue some of similar fabric seemingly to the last assume a shred-like appearance, and are called papillæ filiformes; while a fourth class remains, that are interspersed among the papillæ conoïdeæ; they are termed papillæ fungiformes: they are dispersed in great numbers along the sides and towards the tip of the tongue. Of these papillæ the last alone are thought to belong to taste; they are vascular and erectile, and may be observed to shoot up upon the surface of the tongue, when it is touched by a sapid substance. No similar papillæ, however, are discoverable on the soft palate.

When sapid substances, such as salt, sugar, aloes, tartaric acid, are applied to different parts of the interior of the fauces, they are found to excite the most distinct sensation at the tip and edges of the tongue: they produce no sensations of taste at the fore and upper part of the tongue, or on the hard palate. But at the back of the tongue they again excite sensation enough to be distinguishable, and they are still more perfectly tasted upon the middle of the soft palate and uvula. The participation of the soft palate in the sense of taste has been recently pointed out by MM. Guyot and Admyrauld, and has been carefully verified by Mr. Wheatstone and myself. We did not find that one taste was perceived more distinctly than another at any point of the tongue or soft palate.

In order that a substance may excite the sensation of taste, it must be presented to the tongue in a liquid state: to promote this object, when a solid is placed in the mouth, the saliva flows abundantly; the sapid qualities of the food are perceived in proportion as it dissolves: in like manner an aëriform fluid is tasted as soon as the moisture of the mouth becomes impregnated with it.

Various substances, after exciting the sense of touch on the fauces, and that of taste upon the tongue, are capable of producing a third impression, which is popularly referred to the palate, but is really felt upon the sentient membrane of the nostrils: the fume of certain kinds of food ascends into the cavities of the nose, and produces this third and distinct sensation: in administering medicine to children, it is well known that the greater part of what is disagreeable in its flavour may be avoided, by closing the nostrils while the draught is swallowed: and by repeating this experiment upon various articles of food, it is easy to ascertain how much of their flavour depends upon one sense, and how much is appreciated by the other. Hence it is that the senses of taste and smell have been often compared as having a resemblance, the odour of many substances being supposed to resemble their flavour; while the fact is, that the flavour of such bodies consists in their scent, and that the two impressions, which are compared, are one and the same.

It follows, from what has been said, that substances taken into the fauces may be such, as either,

1. To excite sensations of touch alone; of this nature are rock-crystal, sapphire, or ice:

2. Or to be felt upon the tongue, and in addition to excite sensation in the nostrils, as for instance tin and other odorous metals:

3. Or to be felt upon the tongue, and in addition to excite sensations of taste, as for instance sugar and salt:

4. Or, finally, to be felt upon the tongue, to be tasted by the tongue, and in addition to excite a sense of flavour in the nostrils, as for instance bread, manna, and the like.

It may be remarked, in addition, that some substances of a penetrating nature, such as peppermint, appear to produce another distinct impression, the seat of which seems to be the back part of the fauces.

Sensations of taste are not perfect until the mouth is closed and the tongue pressed against the palate, by which means the sapid liquid is brought into more exact contact with the surface of the tongue, and perhaps forced into the texture of its mucous membrane, at the same time that its fumes are driven through the posterior fauces into the cavities of the nostrils.

The tongue is supplied by the ninth nerve, which is distri-

tributed through its muscular texture: by the gustatory, a branch of the ganglionic portion of the third division of the fifth, which is distributed nor merely to the muscles of the tongue, but to its mucous surface likewise and to two of the salivary glands: by the glosso-pharyngeal nerve, which gives branches to the surface of the root of the tongue.

After the division of the ninth nerve on both sides in dogs and rabbits, the tongue loses the power of motion, so that when a little drawn out of the mouth it remains protruded, and is not retracted when acrid substances are applied to it, which at the same time evidently produce the usual degree of sensation.

Upon dividing the gustatory nerve, the tongue loses sensation, but its muscles appear to retain their tone.

Upon pinching the gustatory nerve in animals immediately after death, no movement follows of the fibres of the tongue; but each time that the ninth nerve is pinched, the muscles of the tongue are convulsed.

In a case that I witnessed, in which the symptoms present showed that every portion of the fifth had lost its sensibility, the peculiar feeling that belongs to the root of the tongue remained. A vague sensation of touch, attended with a momentary nausea and effort to vomit, ensued, as in healthy persons upon pressing the surface of the root of the tongue with a probe. Upon pinching the glosso-pharyngeal nerve in animals immediately after death, no spasm follows of the muscles of the tongue.

I conclude from these observations, that the ninth nerve is the voluntary nerve of the tongue; the gustatory nerve the nerve of touch and taste; the glosso-pharyngeal nerve the source of the vague impressions of contact and nausea, which are produced on touching the base of the tongue.

Professor Panizza, of Pavia, has recently advanced some very ingenious arguments that are opposed to the opinions which have been stated. The deserved reputation of Professor Panizza, and the evident skill and caution with which the experiments which he mentions were performed, induce me to enter at some length into the examination of his views on this subject. I am acquainted with them through a paper by Dr. George Burrows, in the Medical Gazette of September 1835, from which the extracts that follow are taken.

The lingual branches of the ninth *(motor linguæ)* are held by Panizza to be the voluntary nerves of the muscles of the tongue, in accordance with the opinions of other physiologists.

The lingual branches of the fifth *(nervus gustatorius)* are held by the Professor to be nerves of touch, which again accords with the opinion generally received; but he argues against their being nerves of *taste, as well as of touch,* which they are commonly esteemed to be.

The glosso-pharyngeal nerve he supposes to be the nerve on which taste depends.

Perhaps the best way of treating the question will be to state *seriatim* the experiments of Panizza upon the different nerves, and afterwards the objections, which I think may with reason be urged against the conclusions which the Professor draws from them.

1. *The lingual branches of the fifth pair divided in a dog.*

"If some milk, or bread, or meat, is offered to the dog, he eats and drinks readily, although, after the operation, it sometimes appears that the dog laps up the milk and masticates his food rather slowly, which may arise from the loss of the sense of touch, or in consequence of the deep wound. If, on the other hand, just enough colocynth, or infusion of quassia, be added to the milk, so as to give a bitter taste without altering the colour, or a piece of bread be dipped into this milk, or, indeed, merely a few drops of the bitter liquid poured between the fibres of a piece of flesh, the animal, which up to this moment had evinced the strongest desire for meat and drink, immediately refuses both one and the other, after taking one mouthful of either. If a piece of meat prepared with the bitter solution is mixed with several others, and the dog accidentally takes it into his mouth, he immediately rejects it, and often refuses to eat any more*."

Objection.—The disagreeable impression which the dog evinced may have resulted from the bitter being *tasted* by the soft palate. This objection was foreseen by Panizza: accordingly, Dr. G. Burrows goes on to say—

2. "These facts alone would not prove that the sense of taste still exists in the tongue, because the bitter flavour may be perceived by other parts of the mouth. In order to dissipate all

* Med. Gaz. vol. xvi, p. 850.

doubt, it is therefore desirable that the bitter substance should merely touch the tongue itself; and to accomplish this, it is best to take a small feather, previously slightly dipped in the bitter fluid, and to draw it lightly along the dorsum of the tongue, taking great care that the fluid does not extend beyond the points touched by the feather. With these precautions the animal still evinces the same marks of strong distaste for the flavour."—Pages 850, 851, op. citat.

Objection.—In this experiment the dog's mouth must either have been held open all the time of the observation, or have been allowed to close. In the latter case the bitter would have been applied to the soft palate, an organ of taste. In the former it is not singular (without supposing the creature to have been unpleasantly affected by the *bitter*) that it should have moved its tongue and mouth, as if it experienced something disagreeable there.

3. *The glosso-pharyngeal nerves divided in a dog.*

"As soon as the dog had a little recovered himself after the operation of the division of the glosso-pharyngeal nerves, he licked up some water, and ate as freely as if no injury had been done to him. The animal had no other guide than the sense of smell in the choice of his food, so that he would equally take into his mouth disagreeable and hurtful substances as well as pleasant and wholesome. The dog after this experiment ate with equal voracity plain meat as well as that imbued with colocynth, and equally drank the plain milk and that rendered bitter by colocynth. The dog not only devoured a piece of meat which had been beaten up with some colocynth, but even lapped up the remainder of the liquid in the plate."—Page 885.

Objection.—This experiment proves too much. The middle of the soft palate in man, and it is presumable in dogs, enjoys a strong sense of taste: how came that part not to be disagreeably affected with the colocynth? Besides, there is a tendency in animals, when wounded, to feed; there is likewise a difference of sensibility in different animals; and it is very possible that after such a wound as had been inflicted in this case, the animal should disregard a moderately unpleasant *taste*, when combined with an agreeable *flavour*—that, namely, of milk.

4. Dr. G. Burrows continues—

"Similar experiments were made at the same time with a dog whose lingual nerves of the fifth pair had been divided. After

this latter animal had caught in his mouth several pieces of plain meat which were thrown to him, he readily took in the same manner a piece with the bitter *taste;* but he had scarcely got it *into his throat* before he was seized with vomiting, and he rejected this piece."—Page 885.

Objection.—The direct conclusion from this experiment is, that the animal had no taste in the fore part of his tongue [*the lingual branch of the fifth being divided*]; but that the soft palate tasted the bitter; and perhaps the root of the tongue, through the glosso-pharyngeal, although it did not taste the bitter, might vaguely *feel* its astringency.

5. Dr. G. Burrows continues—

"A most remarkable contrast between the dogs was now observed; for the animal whose glosso-pharyngeal nerves were divided, immediately ate this rejected piece of meat. Nevertheless, this latter animal still preserved his sense of feeling in the tongue; for immediately on its being pricked the dog howled, and attempted to run away."—Page 885.

Objection.—The natural conclusion from this experiment, taken alone, I admit to be, that the division of the glosso-pharyngeal nerves destroyed the sense of taste. Yet it appears equally certain to me that the dog, in this experiment, *may* have tasted the bitter, yet in spite of it, have been attracted by the flavour of the meat. I beg likewise to refer the reader to the *objection* subjoined to the third paragraph quoted.

Perhaps it will be thought that to settle this question, all the experiments of Panizza should be carefully repeated. I have not done this; but the most important of them, and the only one which I had not previously tried, I have performed. I divided, in a dog, on one side the trunk of the glosso-pharyngeal nerve, and on the other the lingual branch of the same nerve. Mr. Kiernan and Mr. Skey, with whose assistance I made this experiment, agreed with me in thinking that the gestures of the animal, when extract of colocynth was applied to its tongue, evinced that it tasted it.

I must confess, however, that I am disposed to draw conclusions with great caution from experiments on the sensibility of animals after the division of nerves. When nature, in place of being interrogated, is put to the question, she often gives false answers. But setting my own experimental observations against Panizza's, as sufficient to throw some doubt upon his observa-

tions, I think the following argument, derived principally from anatomy, perfectly conclusive on the question.

The sense of taste is most acute at the tip and edges of the tongue. But anatomy shows that branches of the glosso-pharyngeal nerve do not reach the tip of the tongue. Branches of the fifth and of the ninth are alone distributed there. And as the latter [the ninth] are admitted at all hands to be voluntary only, or not to impart either taste or touch, it follows that both the taste and touch enjoyed by the tip of the tongue must depend upon the lingual branches of the fifth.

When I assert that the sides and tip of the tongue are the seat of the acutest degree of taste, I state a fact which I have very carefully verified. It surprises me, therefore, that so good an observer as Panizza should represent the *base* of the tongue as having the highest degree of taste.

Dr. G. Burrows gives the following from Panizza:—

"In fact, when the glosso-pharyngeal nerve is diligently examined, either in man or animals, as in the dog upon which these experiments were principally performed, it appears that, without giving off a single filament to the muscles through which it passes, the nerve is entirely distributed to the mucous membrane of the tongue and to the surrounding parts, which, in common with the tongue, enjoy the sense of taste: this sense is most exquisite there, where the filaments of the nerve are most abundant—that is, towards the base of the tongue."—Page 885.

The most singular addition that has been lately made to our knowledge of this function, is contained in an account, by Mr. Noble, of Manchester (given in the Medical Gazette, vol. xv, p. 120), of a patient, who has anæsthesia of one side of the face, from an affection of the fifth nerve. The half of the tongue on that side has lost feeling too; but it tastes. Certainly, physiologists were not prepared to expect this phenomenon. The inference it would lead us to draw, however, is an analogical one; namely, that there are different filaments of the fifth for touch and for taste. In the case reported, one of these sets of filaments may have lost its sensibility, while the other retains it.

The nerves which minister to the sense of taste are the gustatory branch of the third division of the fifth, and the smaller portion of the spheno-palatine branch of the second division of the fifth.

SECTION V.

Of the Sense of Effort.

When we poise any substance in the hand, to estimate its weight, we attend to the impression upon this sense: we measure the weight by the effort necessary to sustain it. The organ of this sense is the voluntary muscles: the nerves which minister to it, however, are probably not the voluntary nerves, but the muscular branches of those nerves which on the skin minister to the sense of touch. The point, however, is by no means determined. The only evidence which we possess is the history of cases of anæsthesia. Their phenomena have been already adverted to, and will be again. The patient with anæsthesia has no feeling in his hands, but he is able to use his hand to carry a weight, if he looks at what he is carrying. When he turns his head away, the weight drops. I think it may be inferred from these facts, that in anæsthesia the sense of effort is lost. If the inference is a just one, it follows that the seat of that sense is the sentient muscular nerves, not the voluntary nerves. But further observations are wanted. Cases of anæsthesia have not as yet been studied with reference to the present question; and the evidence which they are calculated to afford may possibly, upon stricter inquiry, lead to a different conclusion.

Dr. Wells was the first who described this sense, which may be called either the muscular sense, the sense of resistance, or the sense of effort. The term muscular sense is the most objectionable, inasmuch as the muscles certainly possess other modes of sensation in addition, which will afterwards be referred to, sensibility to heat and cold, and to motion.

The sense of effort is one of the most important in leading to the notions which we form of the material world. We derive from it, in the first place, our notion of force. It is true that without it we might have come to the idea of a tendency of bodies to attract each other, or to communicate motion one to another. Vision might have awakened in our minds these ideas. But our notion of physical force practically always involves the idea of the quantity of muscular exertion by which it might be produced. In the second place, the notion of

hardness, and after that of the impenetrability of matter, are derived from this sense. It measures resistance, whether a substance be soft and yielding like dough, or resistant as marble. Our notions, then, of the consistence of matter, of what is meant by solid or fluid or gaseous, are obtained by this sense.

SECTION VI.

Of the Sense of Touch.

The sense of touch has a much more limited sphere than has been hitherto assigned to it. It gives us information of certain characters of the surfaces of bodies, whether they be irregular or even, rough or smooth; for this, however, it is requisite that the substance examined should be moved over the organ of sense, or the organ of sense pressed against or moved in contact with it.

The skin, especially at the extremities of the fingers, the lips, the tongue, is the organ in which this sense is seated. It is, however, found diffused in a vaguer character over other surfaces: the fauces, the pharynx and œsophagus, the rectum and vagina, have a general sense of contact. The nerves which minister to this sense are the ganglionic fasciculi of the fifth and of the spinal nerves, and some of the filaments of the glosso-pharyngeal and pneumo-gastric.

SECTION VII.

Of Sensations of Heat and Cold.

Sensations of heat and cold are perceived wherever the sense of contact or the sense of effort exists. They are most perfect upon the skin and fauces, but the pharynx and œsophagus, the vagina, bladder, and rectum, are in a great degree alive to them; and the voluntary muscles, when exposed in surgical operations, feel them acutely. Even in the stomach, sensations of cold appear to be felt; though it may be a doubt whether the sensation be really excited there or in the abdominal muscles, through the

cold transmitted to the latter, when substances at a low temperature are swallowed. The same nerves which are the source of the sense of effort and of contact, minister to the sensations excited by differences of temperature.

Sensations of heat and cold are relative: the temperature of weather which is mild in winter, appears cold to us in summer. Like other sensations, these again essentially depend not merely upon the present impression, but upon the condition of the sentient organ. Thus a patient occasionally feels chilly, when the surface of his body seems to a bystander more heated than usual. The sensation of cold in the preceding instance is analogous to the perception of flashes of light before the eyes, when an apopletic attack is threatened.

Custom enables the skin to sustain without inconvenience a degree of heat which naturally gives pain, and even to resist the physical injury which it commonly produces. Some extraordinary exhibitions were not many years ago presented to the public, in which there evidently has been no deception, yet in which the operator has applied heated liquids or heated metals to the skin or tongue, without producing that vesication of the surface which another would have experienced under the same circumstances.

SECTION VIII.

Of the Sense of Motion.

There is a feeling attending the sudden beginning or retardation or acceleration of motion, which is independent of the sense of contact excited on one or other of the aspects of the body, and of muscular effort. When one is in a state of equable motion, as when one lies upon the ground (there being then the earth's motion only to be taken into account), or in the perfectly smooth and uniform motion of a boat gliding down a river, we *feel* that we are at rest. Any sudden alteration of the quantity of motion in us we *feel* by the sense of motion. The existence of the same sense may be rendered evident in another manner. After travelling a short distance in a rough carriage [to the city, for instance, in an omnibus], when the carriage has stopped, and you have remained on your seat a few seconds, if you rise suddenly, you feel, for an instant or two, as if the

carriage were still in motion: this is the sense of motion continuing *after the external cause has ceased,*—as the sensation produced by a flash of lightning remains in the eye longer than the light itself.

It is not easy to say where this sense exists; whether in the muscles only, or in the joints and sinews and integuments, or in the whole frame together.

SECTION IX.

On some of the Uses of Sensation.

I. The use of the eye is to see, of the ear to hear, of the tongue to taste, and so on of the rest: but there are certain common ends obtained by, or secondary uses of, sensation, which may now be treated of. As they belong to the exercise of sensation generally, I have postponed their consideration till the nature of each of the special senses had been described. They are of various degrees of importance and interest. To begin with, it may be observed, that, independently of the gratification and knowledge which flow directly from our senses, their exercise contributes in a high degree to keep the mind in a healthful state, to preserve it from visionary scheming and idealism, bringing us back directly to what and why we are, what our designs an objects. The fantastical state of the mind in dreaming results, in a great degree, from the absence of those external impressions which habitually [when we are awake and sane] poise and steady the mind.

II. Sensations, as we recollect them, are pictures, sounds, fragrance, and the like; but independently of what is mere sensation, there are excited in us, by its perception, certain conclusions respecting external nature, the origin of which it is highly interesting to analyze.

The impressions to which I refer, are those of locality, outness, and direction.

a. The idea of *locality*, or a more or less definite impression as to the place of sensation, attends the exercise of every sense. No one, for instance, can doubt that he tastes in his mouth, or smells with his nose, or hears in his head, or that what he touches with his hand he feels with his hand, not with his foot.

b. The idea of *outness,* on which our belief in an external world, in place of a world of dreams, is mainly founded, is not excited by every sense. Smelling, tasting, hearing, do not appear to me to excite it; nor motion necessarily: but it is irresistibly conveyed to our minds by sensations of touch, resistance, and vision. In the last instance alone the fact may appear questionable; yet it is sufficiently proved by the remarkable expression of Cheselden's patient, who, when first restored to sight, drew back, thinking that the objects which he saw touched his eyes.

c. We obtain ideas of *direction* through vision, hearing, resistance, motion, contact.

1. Or to take contact first. Simple contact conveys no idea of direction; but a succession of contacts, as when the point of a pencil is drawn along the skin, conveys to us a positive notion of this relation.

2. The law through which we receive impressions of visual direction has been already explained, under the head of vision. The general expression of the law, it will be remembered, is the following. Each point of the surface of the retina, when excited to vision, sees in the direction of a line vertical to its concave aspect.

3. Mr. Wheatstone has ingeniously conjectured, that our notions of audible direction may depend upon the excitation of the parts of the auditory nerve that are distributed in the semicircular canals: all, however, that we as yet *know* upon the subject [if it deserve to be considered a law of audition] is, that we refer sensations of sound to a direction exactly opposite to that of the wave or impulse which produces them.

4. The idea of direction obtained by the sense of effort is very definite. Every sensation of effort is attended with a consciousness that the direction of the resistance is opposite to the sensible direction of the effort. Or, as in a succession of contacts, the sense conveys immediately the idea of direction.

5. The idea of direction obtained from motion is not immediate. When we are in perfectly equable motion we do not feel the direction in which we move: we do not feel, for instance, that we are turning round the axis of the globe in a direction from west to east. But when the direction of motion is changed, we then are alive to it, either through altered con-

tact and pressure, or disturbance of our equilibrium; and we obtain through these channels further knowledge as to the relation of the new direction to the last.

III. *Of the use of sensation in voluntary motion.* We are apt to overlook the influence of sensation in our ordinary muscular actions. Yet the effort, which we give to every motion, is accurately measured and determined by sensation. The sense commonly employed is the muscular sense. If we have to raise a weight, this sense enables us to exert the force which is exactly necessary. Supposing again that we have raised and are supporting a weight by the hand, the effort, which seems a continuous one, is in fact a succession of efforts; and each, like the first, is measured by the weight we are sensible of. The same sense keeps us alive to the necessity of continuing the exertion, perpetually compelling our attention to it. The phenomena of anæsthesia already adverted to will illustrate this point. When a patient is afflicted with loss of sensation in the hand and fore arm, he is nevertheless capable of directing a deliberate effort to support any weight in his hand that he sees and calculates the exertion necessary for. As long as he continues to attend to the weight he carries, he sustains it in safety. But if his eyes and thoughts are carried off in another direction, there is no sense to guide the muscles to continue their action; they are overcome by the weight which they do not feel, and drop it. In the researches which I made some years ago into the uses of the fifth and seventh nerves, I was led to generalize this principle. Sir C. Bell supposed, that because an animal, in which he had divided the facial branches of the fifth, did not use its lips to take food, the division of those nerves had paralyzed the labial muscles: I pointed out, that the fact might be explained on the supposition that the lips were deprived of sensation only; and additional experiments which I performed showed my explanation to be correct, and at the same time proved the facial part of the fifth not to be a voluntary nerve. In ordinary cases of anæsthesia the eye is the substitute for the deficient sense of touch; the patient knowing that he cannot feel the weight in his hand, looks at it, and by his sight recollects it, and measures the force he has to put out. Sometimes this is reversed, and the sense of touch is substituted for that of vision in guiding muscular action. I happened to observe a blind woman thread a needle; the method which she employed was the

following: — she applied the head of the needle to the tip of the tongue, and moved the end of the thread along the tip of the tongue, *seeing* as it were with the tip of the tongue, or by its fine sensibility guiding the muscular action of the hand that held the thread.

IV. *Of the use of sensation in maintaining equilibrium.*

Nothing appears simpler, or easier, or more natural, than maintaining our equilibrium in standing, walking, running, under common circumstances. Nor does any thing appear more natural and easy than the rapid movement of the fingers of an accomplished musician playing on the piano. Both, however, are equally the results of long and at first difficult practice in the use of muscles under the guidance of more than one class of sensation.

In maintaining our equilibrium we are principally assisted by the muscular sense, which informs us constantly of the degree and direction of the effort necessary for the support of the whole and of each part of our frame. When we move about a room in the dark, touching nothing in our way, the muscular sense alone excites and directs the necessary effort. When in the light, we use vision likewise. We then rest or support ourselves in some sort on visible objects, of which we know from experience the distance. *We lean upon our eyesight as upon crutches.* This is proved to his conviction, when one unaccustomed to look down heights stands on the top of a tower, resting against the parapet: he knows that he is safe, but he *feels* insecure; his eyes no longer support him, and he feels as if he would topple over. Or, any one can walk with precision the length of a room stepping along a single line of plank in the floor: suppose that plank a bridge across a chasm, the insecurity which one would feel in passing over such a bridge is partly real: use would cure him, by enabling him to fix and rest his eyesight on the narrow line he has to traverse, and to disregard the distant and moving objects from which his sight can derive no support.

How much the maintenance of one's equilibrium is the result of practised sensation and muscular effort, is shown by what happens on going to sea. It is long before the passenger acquires his sea legs. At first, as the ship moves, he can hardly keep his feet; the shifting lines of the vessel and surface of the water unsettle his visual stability, the different inclinations

of the planks he stands on, his muscular sense. In a short time he learns to disregard the shifting images and changing motions, or acquires facility in adapting himself (like one on horseback) to the different alterations of the line of direction in his frame.

If the passenger newly at sea betakes himself to his cot, lies down, and shuts his eyes—the ship having little motion—a new phenomenon presents itself. He has excluded, by closing his eyes, visual impressions of unstableness; and lying down, is called upon to make no muscular effort: the muscular sense is not disturbed. He is now sensible of the motion alone; the vessel going before the wind gently rises and sinks, overtopping the light swell. Each change of motion produces a new sensation. As the vessel rises, there is a comfortable sense of support; when it sinks again, overtopping a wave, there is a distressing sense of want of support. This is the most painful variety among the sensations of motion. Animals may be observed to be sensibly alive to it.

In those in whom the motion of a vessel at sea produces sickness, it is this sense of sinking and want of support, which seems to excite tenfold nausea. It is the sense of instability which in some way produces this effect. For if the sufferer opens his eyes, and looks upon the moving lines about him, the nausea is yet further increased: still more, if he rises, and attempts to stand or walk, the disturbance of the sense of equilibrium is then complete.

Giddiness occasioned by turning round causes nausea, upon the same principle with the pitching of a vessel. When you stop, every thing seems to whirl around you, and produces a sense of insecurity and unsteadiness. Some persons, however, are naturally much more sensible to disturbance of the sense of equilibrium than others. It is on the most sensible alone to these impressions that experiments can be made, that will bring out the true relations of these phenomena. The general susceptibility of persons to such impressions may be measured by the effects produced in them upon looking down heights. A person who is rendered giddy by so doing, is commonly unable to bear the motion of a swing, or of a ship at sea, or to look at a mirror when swinging backwards and forwards. A person of this idiosyncrasy told me, that when angling in a large sheet of water into which he had walked a little distance from the shore,

the wind causing a considerable ripple, and the expanse of water being large enough to fill nearly all his vision, the most distressing giddiness supervened, which forced him to turn and make for the bank. On repeating the experiment, exactly the same feelings returned.

The following observations go to establish an intimate connection between the visual sense of disturbed equilibrium and the feelings of nausea which often go with it; and throw light upon the general relation between vertigo and impressions on the senses.

If a person on the deck of a vessel be slightly disposed to sickness, he has only to lie down and shut his eyes, and the sickness goes away: he has excluded the vision of so many shifting lines and surfaces. On the other hand, if a person after much fatigue drinks hastily three or four glasses of wine, it gets into his head; and then, if he closes his eyes, every thing appears in a whirl around him, and a sense of nausea supervenes: but if he opens his eyes, and fixes his sight on any stationary object in the room, the inward whirl from the altered cerebral circulation vanishes before the steady impression upon the sense, and with the giddiness the nausea disappears.

The giddiness which persists after one has turned round quickly several times in succession, is a complicated phenomenon. The person not only feels giddy, but has a disposition to move his eyes and limbs and frame after or in the direction of the whirling sensation. The continuance of sensation in this instance, after the physical cause is over, is the result of a law common to most of the senses. The light of an electric spark, which really lasts but the eighty-thousandth part of a second, seems to last upon the eye the eighth part of a second. Tastes and flavours last upon the palate and the nostrils in like proportion. So the *feeling* of disturbed equilibrium lasts for a considerable period in the frame generally. Mr. Wheatstone communicated to me a singular observation, which proves that the giddiness produced by turning is an affection of the senses, not of the brain, and that the sense of motion may be involved in its production. If a person, while turning round quickly, holds a large sheet of paper before and near his face, so as to exclude all sight of the room, and fixes his eyes upon a point—a letter, for instance, in the middle of the paper—when he

stops, he finds his head perfectly steady; his eyes have no motion, and the walls of the room appear to him as stationary as if he had been sitting still. His legs, however, are not in a corresponding state of stability; they feel unsteady, as if actually still turning round, which they are strongly disposed to do.

V. *Observations of direction displayed by animals.*

There is a use of sensation, of which animals avail themselves, and to which there is nothing exactly parallel in the anomalies of human partial talent. This is displayed in the power which they occasionally evince of finding their way home from great distances by new routes.

This faculty must turn upon a different principle to the migratory instincts of birds, the nature of which is more easily conceivable. One may imagine the sensations of a bird determining it instinctively to make a long flight at a particular season of the year; and that from or with the sun or the like, guided by the general aspect of nature. But an instinct to find one's way home, is an expression that conveys no idea. Let me, however, exemplify the power in animals, of which an explanation is to be given. The following instance is from Kirby and Spence's Entomology.

" In March, 1816, an ass, the property of Captain Dundas, then at Malta, was shipped on board the Ister frigate, Captain Forrest, bound from Gibraltar for that island. The vessel having struck on some sands at Point de Gat, at some distance from the shore, the ass was thrown overboard, to give it a chance of swimming to land; a poor one, for the sea was running so high that a boat which left the ship was lost. A few days afterwards, when the gates of Gibraltar were opened in the morning, the ass presented itself for admittance, and proceeded to the stable of Mr. Weeks, a merchant, which he had formerly occupied, to the no small surprise of this gentleman, who imagined that, from some accident, the animal had never been shipped on board the Ister. On the return of this vessel to repair, the mystery was explained; and it turned out that Valianté (for so the ass was called) had not only swam safely to shore, but, without guide, compass, or travelling map, had found its way from the Point de Gat to Gibraltar, a distance of more than 200 miles, through a mountainous and intricate country, intersected by streams; and that in so short a period that he could not have made one false turn."

There are numerous instances of a like kind, only less striking, that are perfectly authenticated. How are we to explain them? I think there can be no doubt that the animal is guided on these occasions by a general recollection of the direction in which it travelled from home. The question is, by what sense was that direction estimated? In several cases the animal has been inclosed in a sack or a basket; the distance travelled has been many miles; and the turnings made in its carriage have been endless; and the place to which it has been carried has been one it had never visited before. In such cases I conclude that the sense which the animal has employed has been the sense of change of motion, aided by the sense of contact.

We may suppose the animal alarmed at its new situation, and bending all its powers of observation upon where it is going, and the means of escape: it appears to me not beyond probability, to imagine that the animal observes each turn its path makes, and so draws a correct inference as to the general direction in which it has travelled. I hardly think such an effort more wonderful than that of a practised instrumental performer, who, after hearing for the first time the overture of a new opera, can play it without missing a bar. In the cases of accurate observation by animals now referred to, it may again be supposed that all animals of the same kind are not equally gifted: and another aid may often come accidentally to assist the performance of the feat; after travelling in a direction generally true, the animal, reaching at last the neighbourhood of home, may come upon some familiar track that may be its final guide.

CHAPTER XI.

OF VOLUNTARY MOTION.

The subjects which are to be considered in the present chapter admit of being arranged under six heads: — 1. The nature of the bones and joints, and the general mechanism of the skeleton; 2. The voluntary muscles and their tendons; 3. The attitudes and movements of man; 4. The facial muscles, or physiognomical expression generally; 5. The mechanism of breathing; 6. The voice.

SECTION I.

The Bones and Joints.

Whoever would obtain a profound knowledge of the animal frame must make the bones not only his first, but his principal and constant study. The bones are the parts to which all the other organs are shaped and moulded: or, to speak more correctly, the several organs of the body are indeed formed together, and reciprocally moulded to each other's figure; but the bones being hard parts, retain the cast and impression of the rest, and being the only hard parts may practically be viewed as afterwards determining their place and disposition. Again, the bones, after being macerated, are so easily preserved, and are of such convenient reference and study [compared with other parts of the body], that, if there were no other reason, it would be worth while to associate one's knowledge of the interior of the frame with these organs, as a note-book of easy reference by which to refresh one's recollection. But, as regards the practical study of the living body as the subject of the medical art, a knowledge of the relative position of other parts to the bones assumes a new importance. Though the bones present here

and there only visible salient points, yet by the touch they are everywhere distinguishable, and their several parts and processes determinable with precision. Whoever therefore knows the relative place of the different soft parts to the bones, has the means of telling exactly where each of the former is located in the living frame. If he wishes to expose a particular artery, or to avoid it; if he wishes to ascertain the part which is the seat of inward uneasiness, he has only to calculate the relations of the vessels or viscera of that region to the bones.

But the study of the bones in connection with other organs has broader relations, when applied to comparative anatomy. The shape of the bones declares what classes of muscles have been developed, the form of their articular ends, manifests the kinds of motion which have belonged to the frame; to the kind of motion, the habits of the animal, the nature of its food, the construction of its digestive apparatus, and its whole interior frame, must have had a definite bearing. Thus it may happen that a single bone found by a naturalist may enable him to determine, not only the size, but the complete form and structure of the being to which it belonged.

It is in the study, however, of fossil remains that osteology most asserts its speculative importance. The bones, from their mineral character, have a permanency and exemption from destruction and decay which other parts have not. So we find in the strata near the earth's surface fragments of skeletons of animals, now unknown, that once peopled our globe. These fragments the skilful osteologist is capable of combining with certainty, to form the skeleton of the præ-Adamite animal, formed when the globe was other than it is, and fitted for other living beings than the present; but though different, bearing a sufficient analogy to existing races to enable us to judge of the genera to which they are cognate, of their nature, their powers, their habits, and dispositions.

The interest of osteology is inexhaustible. The sculptor or painter who would acquire facility and correctness in drawing the human frame, must begin with the skeleton; and in each figure that he designs when accomplished in his art, he must still see the skeleton within the outline, to be sure of its general truth of drawing, as well as of expressing properly the subordinate markings that in the limbs indicate the forms of the articular ends of the bones. And there is this in Nature, as con-

trasted with human design. An artist who copies with interest and delight the fine remains of the most perfect specimens of architecture, the task completed, feels that he has mastered all the science and principles of harmony and proportion that the object contains. His curiosity and taste are satisfied. This is not the case when any of Nature's works are our study. When, for instance, we bend our art to pourtray the skeleton, even where a part of it only, or a single bone, is the subject of observation, I know, from having experienced the satisfaction I describe, the pleasure which grows with the continued contemplation of each portion of this frame-work of our body, when we pore over it with the attention which copying it as an artist requires.

I am supposing, indeed, that the artist pursues these studies with his mind alive to the physiologieal relations of the subject: that in tracing the shape and markings of the bones, he considers their uses, their coadaptation to each other and to the sinews and muscles, their proportions and relation to the entire frame.

A sense of its utility is necessary to the perfect enjoyment of what is beautiful. A conception of the purposes contemplated in them is requisite, to draw out adequately those emotions of admiration which the noblest works of Nature are calculated to excite in us. The uninstructed peasant surveys with wonder the spangled heavens. How inferior is his delight to that of the philosopher, who sees in these shining orbs, the skeleton of the world, enormous spheres moving by sublime and simple laws; the physical frame of the universe of which the spirit is God.

It is not otherwise with the study of the microcosm of the human frame: it is full of beauty; but that beauty is cognizable only by intelligence that can comprehend its objects, and therefore distinguishable only partially, here and there only, where we possess those elements of knowledge which enable us to comprehend the design intended, and the perfectness with which it is executed. It is evident that these considerations tend to elevate very highly the study of the present branch of our subject. The laws through which we feel, think, and have our vital being, are calculated only to excite wonder. We do not know why they might not have been otherwise, and why all is as we see it. Not so with the mechanical structure of our frame:

its provisions we can estimate and admire, its weight and strength, the disposition of the forces which operate on it, the congruity and harmony of the whole.

Thus strong are the grounds upon which the student must learn to consider osteology [often estimated by the beginner as a dry and tedious study] as the most important, the most useful, the most satisfactory portion of anatomical science.

When sections are made of a macerated and dried bone, it is found to be composed of two parts; externally of a compact crust of greater or less thickness, and internally of a series of delicate bony threads, which form a close network, or lattice-work, or cancellated structure, the spaces or cells between which freely communicate.

The bones of the skeleton affect three principal forms, each of which has some peculiarity in its structure, adapted to the object upon which it is employed.

The *flat bones*, as they are termed, are those which form the walls of the great visceral cavities, the cranium, the chest, the pelvis. In these bones the crust is thin, and disposed in what are called tables, an outer and an inner: the interposed cancellated structure is termed the diploe. The two tables of the flat bones are for the most part parallel. In the skull the inner table is of a closer grain and of greater density than the outer. The flat bones are externally convex, — a circumstance which contributes with the alternating compactness and porousness of their texture to increase their strength.

The *round or cuboïd bones* are small irregular cubes or portions of cylinders, one series of which forms the vertebral column, another the wrist, and a third the instep: their crust is yet thinner than that of the flat bones; their internal structure varies in different instances: the cancelli are fine in the vertebræ, coarse in the tarsal and carpal bones. The texture of cuboïd bones is therefore any thing but brittle, and is well calculated to deaden the force of jars and concussions of all sorts. To promote the latter object, the cuboïd bones are placed not singly but in groups, so that the elasticity resulting from many joints and intervening layers of cartilage may add to that resulting from their texture. Another advantage is obtained by forming the parts described of many bones; a considerable extent of motion may exist in the entire

part, at the same time that no single joint has play enough to risk its security.

The *long or cylindrical bones* are employed as levers upon which the muscles act when supporting or propelling the body. The extremities of a cylindrical bone, where it is articulated to those adjoining, as they have the office, so likewise have they the structure of the cuboïd bones—a thin outer crust, and strong cancelli: they likewise generally affect a considerable breadth, which increases the strength of the joints. But the intermediate part or shaft of a long bone is constructed differently; its crust is of great thickness, from one-fourth to one-third of an inch; while the internal cancellated structure is remarkably fine and delicate. The bony matter, spread out in innumerable plates and fibres in the broad articular extremities, in the shaft is condensed into a close and compact structure, in order that the lever which it forms may not be flexible: the shaft is cast into a hollow cylinder, for the purpose of giving greater strength through the increase of the thickness of the column. Or, to illustrate the advantage in another way, the shaft is hollowed to give it lightness, at the same time that the removal of its centre does not materially diminish its strength, as the violence which threatens transverse fracture is resisted by the outer crust alone of a solid cylinder.

When a bone is calcined, the earth which remains has the same form and structure as the bone possessed; but it is brittle, and falls in pieces almost from its own weight. If a bone is steeped in acid, it retains its form and structure, but becomes flexible.

The following table exhibits the composition of calcined human bones, according to the analysis of Berzelius.

Phosphate of lime	81.9
Fluate of lime	3.0
Lime	10.0
Phosphate of magnesia	1.1
Soda	2.0
Carbonic acid	2.0
	100.0

Bones when forming part of the living body are covered with a membrane termed their external periosteum, which is easily

detached from their surface; it is thin, except where tendons or ligaments are inserted. All the cavities in a bone again are lined with a fine membrane termed the internal periosteum: within this another membrane is contained, from which is secreted the oil which forms the marrow.

Upon examining the bones in a subject minutely injected with size and vermilion, blood-vessels may be traced through their entire substance. Neither lymphatics nor nerves have been followed into bone; but absorption evidently takes place during the growth of bone, or the cavities of the long bones could not enlarge proportionally. During health, bones are perhaps insensible: during disease, they exhibit acute sensibility.

The modes in which the bones of the skeleton are joined together are very various: in some instances no motion is allowed between adjoining bones, and they seem to have been left disunited with the sole object of diminishing the liability to fracture in the part they form. Upon this principle it is supposed that the bones of the cranium are left disunited after their growth is completed. The strength of the immovable joints which are thus left is determined by the shape of the bony edges. In general these are wrought into alternating projections and hollows; so that, to use a term of carpentry, the bones are dovetailed together. In other instances a plate of one bone overlaps a plate of another. The former kind of junction is termed a suture proper; the latter a squamous suture.

In other instances again, where no sensible motion is intended to take place, but where a part has often to resist considerable violence, a portion of white elastic substance termed fibrous cartilage is interposed between two bones, with the extremities of either of which it is continuous; in this manner the ossa innominata are joined to each other and to the sacrum. As a variety in this sort of articulation we may remark, that the true ribs are joined to the sternum by portions of fibrous cartilage, which are received into sockets at the side of the breast-bone, but are not continuous with it: a layer of cellular membrane is interposed between the cartilages of the ribs and the breast-bone, so as to allow a certain degree of motion to take place at the sterno-costal joints during the dilatation of the chest.

In the kind of joint last described, another substance called ligament is generally found in addition. Ligaments are white silvery bands composed of delicate fibres, that are very flexible, but have little extensibility: they are composed nearly wholly of gelatin: they have no sensibility to common stimuli, but straining them gives rise to acute pain.

The joints of the bodies of the vertebræ deserve to be particularly described. In fish, in which the spine is very flexible, the articular surfaces of the bodies of the vertebræ are so excavated, that when two meet they inclose a cavity, the shape of which may be called spherical. This cavity is filled with fluid, which we will suppose to be incompressible, while the margins of the two vertebræ are joined together by the intervention of a ligamentous substance which is highly elastic; thus a double ball and socket joint exists between every two vertebræ, each of which is capable of rolling in every sense upon the ball of liquid contained between the two. In the human spine the same type is followed, but with a provision for much less latitude of motion; the excavation is shallow, the central substance semi-fluid, and the surrounding fibrous cartilage is confined by ligamentous bands of a less elastic substance.

In the two preceding kinds of joints (at least in the human frame), there is no absolute discontinuity; a layer of animal membrane or of fibrous cartilage directly unites the opposed ends of the bones. In other joints the bones being otherwise disconnected are held in apposition by ligaments. The ends of such bones are covered with a layer of elastic cartilage, that their reciprocal pressure may not injure the osseous tissue. And to facilitate their motion on each other, the whole inner surface of the joint is lubricated with a peculiar fluid. The lining surface may be viewed as one continuous membrane. Membranes of this description in many respects resemble serous membranes; they form shut sacs of the finest texture: they can be separated, though not without difficulty, from the ligaments and periosteum which they cover; but they rarely admit of being detached from the surface of cartilages. I have, however, sometimes been able to peel the synovial membrane from the cartilages of joints, and have several times seen its blood-vessels injected. Membranes of this description take their name from the viscid fluid called synovia, which they secrete, and which lubricates their internal surfaces.

From an analysis by M. Margueron, it appears that sinovia is composed of the following ingredients:

Fibrous matter	11.86
Albumen	4.52
Muriate of soda	1.75
Soda	0.71
Phosphate of lime	0.70
Water	80.46
	100.00

Joints which combine these various elements are divided into classes, according to the form which they affect, and the kind of motion of which they allow.

A ball and socket joint, or enarthrosis, like that of the hip, has great security, and at the same time permits very extensive motion.

A joint, in which surfaces nearly plane are opposed to each other, is termed an arthrodia; the motion allowed in such a case is very limited, but takes place in every sense.

A joint which allows of motion in one plane only is termed a ginglymus or hinge joint. Of this joint there are two kinds; in one the motion is angular, as in the knee, — in the other rotatory, as in the joints of the atlas and dentata.

Such are the materials of the skeleton, and the different modes in which they are joined together to form one frame.

When we seek in the skeleton for illustrations of that analogical design, which is distinguishable, not merely in entire classes but in single objects of Nature's workmanship, we remark that the head is not a part which corresponds with any subdivision of the frame, but that it rather seems an epitome of all the rest.

When we compare together the several regions of the trunk, we observe that it is laid out in corresponding organs or pairs of organs on either side of a centre, which is formed by the five lumbar vertebræ. Above the lumbar vertebræ are the dorsal, above these the cervical; below the lumbar vertebræ are the sacral bones, below these the coccygeal. To the dorsal vertebræ and to the sacrum, bones are articulated, which have the double office of forming a visceral cavity, and of throwing to a convenient distance from the median plane the bones of the extremities. The ribs and sternum, the clavicles and scapulæ, form with the dorsal vertebræ an organ strictly analogous to that formed

by the ossa innominata and the sacrum. But the chest for the function of respiration requires to be continually altering its dimensions, and the upper extremity is characterized by the extent and velocity of its movements rather than by strength: to suit both these objects, the chest and shoulder are formed of many bones, that are moveable in various senses; the ribs are capable both of rotating upon their sternal and vertebral joints, and of being raised or depressed upon their vertebral joints carrying with them the sternum; the clavicle again revolves upon the sternum, and the scapula rolls upon the convexity of the ribs. On the other hand the pelvis, as regards the viscera, is intended merely for their support; and if during labour a temporary enlargement of its lower aperture is requisite, the flexibility of the joints of the os coccygis in the female skeleton, with the temporary yielding of the ligaments, affords a sufficient provision for this object: the inferior extremities again require to be articulated to a solid unyielding platform, upon which they may poise the incumbent weight of the trunk and head. The bones of the pelvis are for these reasons few, weighty, massive, and knit together immoveably. Thus accurately do the points, in which a resemblance is wanting between the chest and pelvis, preserve the analogy between these parts.

It is needless to dilate upon the correspondence of the femur with the humerus, of the tibia, patella, and fibula, with the radius and ulna, of the tarsus with the carpus, of the remaining bones of the foot with those of the hand. As mobility is the prevailing character of the upper extremity, the radius plays upon the ulna, the bones of the wrist are so disposed as to form three ball and socket joints, and the metacarpal bone of the thumb moves freely on a hinge joint. As stability is the leading character in the lower extremity, the knee moves in one plane only, the fibula has no motion upon the tibia, the joints of the tarsus do no more than yield sufficiently to break the force with which the frame alights upon the ground, and neither of the metatarsal bones moves on its tarsal joint.

It would appear fanciful to enlarge upon the points of correspondence between the head and trunk. As the vertebral canal contains the spinal cord, the cranial cavity contains the cerebrum and cerebellum; as the main parts of the respiratory organs are contained in the upper cavity of the trunk, and the

digestive viscera are supported by the lower, so the nostrils are the cavities of the fore and upper part of the cranium, and the fauces of the lower part. If the chest supports the organs of prehension, the pelvis those of pursuit, the orbits, the nostrils, the cavities of the temporal bone, have points in common with the former, and the fauces, which contain the tongue, have a trivial analogy with the latter.

When we consider the human skeleton as designed for beings distinguished by the erect posture and erect progression, and as a frame-work likely to be exposed to violence, yet endued with strength to resist it, the following circumstances attract our notice.

1. The foramen magnum occipitis is situated nearer the centre of the base of the skull in man than in quadrupeds, for the evident purpose of allowing the skull to be balanced with little muscular effort on the vertebral column. The lower cervical and upper dorsal vertebræ are, with reference to the same circumstance, deficient in man in those processes to which the strong ligamentum nuchæ of quadrupeds is attached,—required in the latter to give permanent support to their pendent head, and economizing muscular exertion. The vertebral column becomes uniformly broader towards its base; or if at one part its progressive increase seems interrupted, it is but where the ribs and sternum give it towards the middle of the back an adventitious strength. The upper margin of the acetabulum is the deepest and the strongest. The centre of gravity is situated in or but little above the centre of a line connecting the axes of the two acetabula, so that the head and trunk and arms of a standing person may be swayed to any extent forward or laterally without risking the security of the posture.

2. The lower part of the vertebral column does not rise vertically from the pelvis, but is inclined obliquely forwards; so that when the trunk is carried forwards by a sudden spring, the resistance of its inertia does not strain the ligaments between the sacrum and the last lumbar vertebra, or between any two vertebræ exclusively, but telling first upon the inferior surface of the lowest vertebra, is then thrown upon the ligamentous connections of several bones, which form a column so curved as to share the strain between them. The vertebral column thrown backwards in the dorsal region, thus deepens the cavity of the chest, and throwing the shoulders yet farther

back, tends so much the more equally to distribute the weight of the frame before and behind the axis of the spine. The spine, composed of twenty-four spongy bones, united by soft and elastic substance, is by the nature of its materials admirably qualified to take off the effect of jars or concussions from the head, when from a state of rapid motion the frame alights upon the feet; a purpose for which its curved form renders it all the more available. The spinal column rests on an elastic hoop, in the extreme circumference of which on either side the deep cups are wrought, which receive the heads of either thigh bone. But this elastic hoop is not disposed vertically, but slants in such a manner, that when we alight upon our feet, the force of the arrested motion tells in great measure on the extensor muscles of the hip. The neck of the thigh bone is oblique, to disengage it from the pelvis: the shaft is oblique in the opposite direction, to bring the knee vertically below the hip. The numerous joints of the foot, to conclude, each allowing of very trifling yielding, render the entire arch the more secure; and the astragalus, which directly receives the weight of the body from the tibia itself, rests immediately upon the trochlea cartilaginea, a thick and strong elastic ligament, which, the more it is depressed, the more tightly does it hold together the vaulted frame-work of the foot.

3. What is most admirable as regards the strength of the skeleton, does not consist in an indefinite power of resisting violence, but in the surprising amount of security imparted by their shape, and number, and modes of articulation, to such frail materials—in the equal strength of the whole—in its proportion to the sensibility and power of exertion and endurance in the soft parts, and to the risks to which it is in the common course of events exposed. In the cranium especially, physiologists delight to notice the strength derived from its arched form;—the partial thickening of its most exposed and prominent parts; — its texture strengthened by being wrought in three layers of varying density; — its sutures, which concur with the last-named provision in diminishing its brittleness, and their well-known squamous configuration at the side of the head, enabling the sphenoïd and temporal bones to resist the pressure outwards at that part, when the vertex is forcibly struck *.

* I take this opportunity of recommending to the perusal of the student Dr. Arnott's "Elements of Physics."

The physiology of the skeleton is peculiarly adapted to furnish popular illustrations of the design evinced in the human frame. With this object in view, I will mention one or two other provisions, in addition to those which I have already explained in treating this part of my subject.

The five lower cervical vertebræ enjoy the same kind of motion with the vertebræ below,—motion equal in every direction, yet extremely limited between each pair of bones. But the atlas and dentata have articular surfaces adapted for movements of a much more extensive nature. The ligamentous structure, by means of which the spinal marrow is here secured from injury, is a common theme of admiration. At the same time a provision, the extent of which is perhaps not equally understood, is made for the safety of two great vessels of the brain, the vertebral arteries. For the purpose contemplated a canal is formed, in which these arteries are lodged, by perforations in the transverse processes of the cervical vertebræ. Now the axis of this canal in the five lowest vertebræ is *vertical:* the motion between any two of *these* bones is inconsiderable; the artery therefore, although straight, is not in danger of being strained. But above, where the atlas and dentata have a wide extent of motion, the axes of their perforations are observed to be *oblique.* At the same time the part of the artery between the dentata and the atlas, and that between the atlas and the occiput, are found to be more than twice as long as the vertical height of the intervals requires. At each of these intervals the artery describes a semicircle, towards which figure it derives its bent, from the obliquity of the axes of the bony canals. It runs, therefore, no risk of straining or undue extension during the utmost motions of these bones with each other and with the occipital. The artery is then only unbent, not stretched, in consequence of the disposition which has been explained. But Nature delights in obtaining by one contrivance more than one important end. The double curves of the vertebral arteries are in truth no less essential for their own preservation, than for protecting the soft texture of the brain by diminishing the impetus of the blood transmitted to it.

I think that nothing is more admirable than the joints. Take for instance two that are comparable in their general uses, but in which certain peculiarities admit of the introduction of some difference of structure with advantage—the elbow and the knee for example.

The elbow and the knee are both hinge joints, in which it is required for the strength or security of action of the limb, that there should be a limit, at which its motion in extension should be mechanically arrested; that limit being attained where the two parts of the limb, instead of enclosing an angle, form a right line.

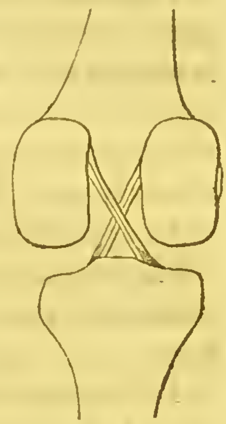
The stop to the extension of the elbow is managed by a very simple contrivance. The olecranon or humeral end of the ulna is shaped into an articular surface that exactly fits the pulley-like surface of the inner condyle of the humerus; the extremity of the olecranon is a process of bone of great strength, which ends abruptly in a broad projecting beak, that is adapted to catch in a deep fossa in the posterior surface of the articular end of the humerus, in such a manner that the bones are firmly locked, when the joint has reached the position of complete extension.

In the knee joint a similar provision might have been employed with equal advantage, as far as the giving the knee stability in extension is concerned. But there would have been this disadvantage: the process of bone must have been of considerable length. In flexion of the knee it would therefore have formed a projection, of which the principal feature would have been its liability to injury. The knee is in everybody's experience a part continually struck; this process of bone would therefore have been perpetually broken off. So Nature employs other means to obtain her object.

These means are the following. The tibia is strongly tied to the condyles of the femur by the crucial ligaments, the course of which is given in the adjoined figure. They are attached at points of a horizontal line passing through the knee, which forms an axis, a segment of the circumference of which is described by the posterior surface of the condyles. In this curve the tibia moves during the flexion of the joint, the crucial ligaments remaining tense, but not interfering with the motion. Now if the front of the condyles had been a continuation of the same circle [this idea is imaged by the dotted line] which their posterior aspect forms, the knee joint might have bent each way, forward as well as backward, and it would have had no position of stable exten-

sion. But that is not their figure; they are produced in a tangential line to the dotted circle; and being so produced, and the crucial ligaments being inextensible, it is evident that a perfect check to further motion forward, that is to say stable extension, is obtained.

The crucial ligaments present another advantage of adjustment: when viewed in front or from behind they are seen to cross each other in the manner shown in the adjoined figure. Why should this be? The disposition appears to me intended to give them the additional force of lateral ligaments. Had their fibres been disposed both in the same planes [which must have been vertical], they would not have checked lateral flexion: disposed as they are, it will appear evident, on inspection of the diagram, that each prevents lateral motion of the tibia in one direction.



But in the knee joint, the analogue of the olecranon still finds its place. This is the patella, which is a true olecranon, only united by ligament, not by bone, to the tibia. Being united by ligament, it is of no use in checking the extension of the joint: but still it serves a purpose: it protects the joint from the effects of blows and hurts, which it is perpetually receiving, and which, had they fallen upon the softer textures, would have been the certain occasion of frequent disease.

The study of the hip joint is not less interesting. There are two points in its construction that have particularly struck me: these are the provisions to limit rotation inwards and outwards. The rotation of the femur outwards is limited by the strong anterior fasciculi of the capsular membrane. It is very necessary that such a provision should exist, or dislocation inwards of the hip would frequently occur. It is equally necessary that the rotatory motion of the femur inwards, beyond certain limits, should be prevented: if it were not, dislocation of the hip outwards would frequently occur. But this necessary check or limit could not be obtained in the same manner as the first, without the introduction of a long thick incommodious fold of ligamentous membrane behind the neck of the bone. This means Nature does not adopt; but in its place introduces within the joint a ligament called the round ligament, which

is of a length exactly to stop the rotatory motion outwards, when its further production would endanger the joint. But a ligament in the interior of a joint, on which so much pressure is made as on that of the hip, would be liable, without some special provision, to become diseased through the pressure: to prevent this result, there is a notch cut at the bottom of the joint, in which a bed of fat is laid, and which exactly corresponds in length with the ligament, and keeps it always out of harm's way.

SECTION II.

The voluntary Muscles and their Tendons.

The nature of the muscular tissue has been already described. That which ministers to voluntary motion does not differ in its structure from that which forms involuntary muscles: but whereas the latter are disposed as tubular coats around the hollow viscera, the voluntary muscles invest the skeleton, extending from bone to bone.

The muscles of the trunk and limbs have at least two attachments to bone, one of which is called their origin, the other their insertion. The former term is usually applied to that attachment which is nearest the centre of the body, or which under ordinary circumstances is the fixed point during the action of the muscle. By its origin and insertion a muscle adheres to two separate bones, which either are articulated together, or have a third bone or even several interposed. In the latter case a single muscle is adapted to bend or extend several joints.

Muscular fibres in some instances adhere directly to the periosteum of a bone, in others they are united to it by an intermediate cord of a structure resembling that of ligament, termed a tendon or sinew. The greater number of muscles of the class under consideration have a tendon at one extremity, and commonly at both some tendinous fibres are wrought into their texture.

Some have illustrated the connection between a muscle and a tendon in the following manner. Each fasciculus of a muscle, as it has been already remarked, has its sheath of membrane; we have but to suppose this sheath prolonged beyond the termination of the fibre, as a compact thread, and

we have a tendon produced. On this supposition the definite proportion between the strength of a muscle and that of its tendon would be essentially provided for by an union of threads in the texture of the latter, equal in number and coarseness to the fasciculi of the muscle. The threads of which a tendon is composed are never plaited and are rarely twisted : they are, in almost every instance, collected into fasciculi which are simply laid side by side, and strongly cohere.

The various uses which tendons serve require an elaborate explanation.

The strength of a muscular fibre does not alter with its length. A long and a short cord of the same texture and thickness require an equal force to tear them asunder. The strength of a cord is that of its weakest point. It must be the same with a muscular fibre. We may suppose the contraction of a muscular fibre efficient at any degree below the maximum force of its weakest part; but if the resistance opposed to it exceed the strength of the latter, it is obvious that the extension or rupture of the fibre at that part will neutralize the force of the rest. All that the remaining parts of a muscular fibre can do, is by exerting an equal force with the weakest to prevent the waste of any of its effect.

But the extent to which a muscle can shorten, depends upon the length of its fibres. It is ascertained that a muscular fibre is capable of contracting to a limited degree only. When a limb has been broken, and through ill management has become materially shortened, its muscles are for a time rendered useless, although they subsequently accommodate themselves to the altered length of the limb. Let us assume, then, that a muscular fibre in action can only diminish its length by one-third : it follows, that a muscular fibre of three inches in length would in its utmost contraction bring its points of attachment an inch nearer than before, whereas a muscular fibre a foot in length would be capable of reducing the distance between its points of attachment four inches *.

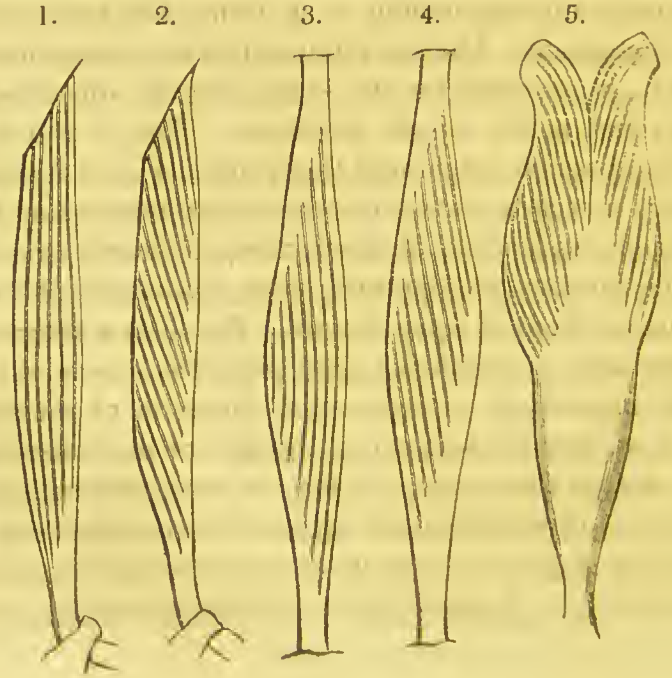
Now let us suppose, that the distance between the origin and insertion of a muscle is one foot, but that the necessities of the frame never require that its attachments should be brought nearer than eleven inches. It is obvious that in such a case three-fourths in length of the muscular fibre would be

* A muscle can probably contract to three-fifths of the length which it presents in its relaxed and elongated state.

useless, and that their place might as well be supplied by an inextensible substance. In the wise economy of Nature this circumstance has not been overlooked: in cases similar to that supposed, as in the instance of several of the muscles which move the wrist, tendon is used in place of an unnecessary length of muscular fibre, and a considerable expense of muscular power is saved.

In the instance given of the tendon of the fore-arm a provision is made for symmetry. The graceful outline of the leg and ankle is produced in a similar manner, the volume of the limb being diminished at the lower part by the substitution of tendon for muscular substance. Upon other occasions the same object is attained by a different contrivance. The leg, to pursue the last illustration, would certainly lose its symmetry, if it had a calf on the fore part; or in other words if the muscles, which bend the ankle joint, formed a short thick mass of flesh below the knee, with tendons tapering to the instep. Instead of this arrangement, the short fibres, which belong to the extensors of the toes, rise from the whole length of the tibia and fibula; and each muscle has a long tendon beginning at its upper part, to which its fibres are inserted in succession, so as to produce a resemblance to the feathered part and stem of a quill: muscles of this appearance are hence termed pennated muscles. The advantage which they present is the substitution of strength that may be wanted, for extent of motion that is not wanted.

1. 2. 3. 4. 5.



Figures 1 and 2 represent two muscles of similar bulk: fig. 1, a muscle with longitudinal fasciculi; fig. 2, a pennated muscle. It is evident that though the fibres in fig. 2 are shorter, yet that they are much more numerous than in fig. 1: fig. 2 represents therefore a much stronger muscle, but one of less extent of contraction than fig. 1.

Sometimes it happens that the symmetry of a limb is best consulted by interposing the muscular substance between two tendons: the rectus femoris thus has a long tendinous origin as well as a tendinous insertion. In this and similar cases a second advantage is gained: a tendinous attachment occupies a much smaller surface of bone than a muscular attachment.

The attachment of a muscle to bone is fleshy instead of tendinous, when it is requisite that different fasciculi of the same muscle should draw in different directions, as in the instance of the glutæus medius and glutæus minimus, or when the muscle through this means obtains a more convenient form, as is the case with the obturator internus.

In the rectus femoris, the semi-membranosus, and other muscles, in which a mass of muscular substance is interposed between two tendons, each tendon forms near its attachment a strong thick cord, but spreads out, and terminates as a membrane towards the belly of the muscle. It is to be remarked, that in these instances the two membranous expansions are formed upon opposite sides of the muscle: if, for instance, the upper membraniform tendon is in front, the lower is situated behind the muscle. The end attained by this arrangement is very apparent: it provides for the equal length, and consequently for the equal action of all the fibres. Figs. 3 and 4, of the preceding diagram, exemplify this point. Fig. 3 represents an imaginary muscle with two membraniform tendons on the same side, which renders the fibres of unequal length: fig. 2 represents the tendons on opposite sides, by which the intervening fibres are kept of equal length. Fig. 5 is a diagram of the gastrocnemius, in which the same principle is exemplified.

In the majority of instances the direction of muscles is parallel, or at least not vertical to, the axis of the bone which they move; so that their action is for the most part oblique. It is obvious that this application of force is attended with a considerable loss of power:—an advantage however of another kind is gained by it. A muscle thus disposed is capable of moving

the point of its insertion through a large space, while the extent, to which it *shortens*, is very trifling. The action of the supinator radii longus may serve to illustrate this position: but the action of the intercostals is more obvious, and is the instance more commonly selected.

The muscles of the trunk and limbs are distributed in a double series, the one as antagonists to the other: nevertheless those, which on one occasion are directly opposed to each other, on another may act in concert. Thus the use of the pectoralis major is to carry the arm forwards, that of the latissimus dorsi, to carry it backwards: but both may concur in simply depressing the arm.

The problem solved in the direction and place assigned to different muscles is probably, in what manner they should be disposed, in order that they may individually combine in the greatest variety of actions, and that one type may serve for the frame of numerous families of animals with habits essentially different. It is a remark not without the profoundest interest, that in many instances parts serviceable in one animal are found to exist in others where they are evidently useless,—if indeed that provision is useless, which stamps the strongest evidence of an uniformity of design in the various families of animals, by leaving vestiges of organs in one race, which only find their physical importance and development in other beings.

The plantaris is a part of this description. In simiæ this muscle is expanded into the plantar fascia, and gives tension to that membrane, with the object of protecting the plantar vessels and nerves, when the prehensile foot of the animal grasps any hard substance. In man the foot is not prehensile, and the plantaris is not wanted: it exists, however, as a vestige, but goes no further than the heel bone.

As it might be expected, various theorems in mechanics find an illustration in the common frame of the bones and muscles. In every movement of the body a lever of one kind or another is set in motion.

A lever is supposed to be an inflexible line, which is moved upon a point termed its fulcrum, that is placed either at one extremity or intermediately, by a force applied at a different part, so as to overcome a resistance which operates upon a third point of the lever. Three sorts of levers are formed by varying

the relative place of the fulcrum, the power, and the resistance. In the first, the fulcrum is intermediate, in the second the resistance, in the third the power.

The mechanical advantage of a lever is easily estimated ; the power or the resistance has the advantage in proportion to its relative distance from the fulcrum, or in proportion as the length of the arm on which the one operates exceeds the length of the arm on which the other operates. An equilibrium is produced, when the force and resistance, and the distance of each from the fulcrum, are equal.

On the other hand, in proportion as power is sacrificed, velocity is gained. Whenever the resistance operates upon the longer arm, the weight lifted traverses in the same time a greater space than the point at which the force is applied. Now rapidity appears to be a more important object to be attained in the movements of the animal frame than mechanical force: accordingly in most instances the third kind of lever is employed, which essentially involves a greater distance between the resistance and the fulcrum, than between the power and the fulcrum. To such an extent is this principle carried, that in order to balance a weight of one pound in the hand, the biceps flexor cubiti, if it were possible to suppose it acting alone, must exert a force equal to ten pounds.

On many occasions velocity again is obtained by the simultaneous extension of several joints, which move in concert to one object. Thus when a straight blow is struck, the hand moves forward with greater velocity than is communicable by a single set of muscles ; at one and the same instant the humerus is raised, the fore-arm depressed [the fist, impelled by two forces, moving in the diagonal], the scapula advanced, the body rotated.

The only instance, in which the second kind of lever is employed in the human frame, and velocity sacrificed to mechanical power, is to be found in the foot : — the tendo Achillis is attached to one extremity of the lever, upon an intermediate point of which the weight of the body rests when in stepping forward we rise upon the ball of the great toe.

The strength of muscular fibre is unknown : but it is supposed, that a muscle, the transverse section of which would present a surface an inch square, might exert a force equal to five hundred pounds. It seems likely that there may be an

original difference in the quality of muscles; and that some of greater volume are essentially weaker than others less in bulk but of more rigid fibre. Much, however, depends upon the energy with which the will operates. During frenzy, a slight and slender frame is often found capable of going far beyond the most powerful efforts of the strongest man when acting under less excitement.

The continued action of a voluntary muscle must metaphysically depend upon successive impulses of the will repeated at infinitely short intervals: and a curious observation of Dr. Wollaston's makes it appear, that in a continued muscular effort, the renewal of the muscular contractions may be even appreciable by the senses *.

SECTION III.

Of the Attitudes and Movements of Man.

The body stands, when erect, on the same principle as a modelled image of similar weight: its position is secure, as long as a perpendicular drawn from its centre of gravity would fall within its base. The muscles support the frame erect, by keeping the joints rigid in any attitude which may be assumed involving the preceding condition. The securest posture that could be given to a model, weighted like the human body, would be the securest for the human body. What renders the attitude of standing practically so firm in a living person, is the power we have of anticipating on what side it will be necessary to make resistance, and of increasing the length of the base on which we rest, in the direction in which violence is threatened.

If a person while standing erect be suddenly killed, he drops prone on the ground: the body falls forwards, because the greater part of its weight is placed before the column of support, which, in the supposed case, suddenly gives way at every part where there is a joint. The tendency of the body to fall forward seems provided against accidents of a less grave character to which we are occasionally liable: we thus fall, when

* Phil. Trans. vol. c, p. 5.

we lose our balance, against objects which we see, and towards which our hands and arms are readily advanced to break our fall.

Of Walking.—A description of walking is the description of a succession of steps. The following analysis of the process is borrowed from Magendie's Physiology.

Suppose a man standing, his two feet placed together, and beginning to walk upon a horizontal plane, with a step of an ordinary quickness and length, he must bend one of the thighs upon the pelvis, and the leg upon the thigh, in order, by the shortening of the limb, to detach the foot from the ground. The flexion of the hip joint causes the movement of the whole limb forwards: the limb next rests itself on the ground; the heel touches first, and then in succession the whole lower surface of the foot. Whilst this motion is being performed, the pelvis suffers a horizontal, rotatory motion, upon the top of the thigh of the limb that remains at rest. The result of this rotatory motion upon the head of the thigh bone is, 1st, to carry forward the whole of the limb detached from the ground; 2d, to carry forward also the side of the body corresponding to the moving limb, whilst the side corresponding to the immoveable limb remains behind.

These two effects are scarcely perceivable in short steps; they are strongly marked in ordinary steps, but still more so in those that are long: there is not yet any progression, the base of support only is modified. To finish the step, the limb that remained behind must advance, place itself on the same line, or pass that which went before. For this purpose the foot which is behind is detached from the ground, successively from the heel to the toe by a motion of rotation, the centre of which is in the articulation of the metatarsal bones with the phalanges, so that, at the end of this motion, the foot touches the ground only by these latter. From this motion arises an elongation of the limb, the effect of which is to carry forward the corresponding side of the trunk, and to determine the rotation of the pelvis upon the head of the thigh of the limb that was first moved. This motion once produced, the limb bends, the knee is carried forward, the foot detached from the ground; the whole limb then performs the same motions that were performed by that of the opposite side.

By the succession of these motions of the inferior limbs and of the trunk, walking is produced, in which we see that the

heads of the thighs are by turns the fixed points upon which the pelvis turns as upon a pivot, in describing arcs of a circle so much larger in proportion as the steps are long.

In order that walking may be in a right line, the radii o the circle described by the pelvis, and the extension of the members when carried forward, must (on each side) be equal: without this condition the body will deviate from a right line, and be carried from the side opposite to the limb whose motions are of the greatest extent; as it is difficult to make the two limbs perform successively motions of the same extent, we always tend to deviate from a right line, and would really so deviate, unless we were enabled to correct the error by the eye. We may be easily convinced of this in walking some time with our eyes shut.

Of Leaping.—In this sort of motion the body becomes a projectile, and follows the laws of projectiles.

Leaping may take place directly upward, forward, backward, or laterally, &c.; these different cases have their principal phenomena in common. Every species of leaping requires a previous flexion of one or many articulations of the trunk and inferior extremities; the sudden extension of the bent articulations is the immediate cause of the propulsion of the frame from the ground.

Let us suppose vertical leaping performed in the ordinary manner: the head is a little bent upon the neck; the vertebral column is bent forwards; the pelvis is bent upon the thigh, the thigh upon the leg, and the leg upon the foot; in general the heel presses very lightly on the ground, or quits it entirely.

To this general state of flexion succeeds a rapid extension of all the articulations before bent; the different parts of the body are rapidly raised with a force which surpasses their weight by a quantity which is variable: thus the head and the thorax are thrown upwards by the extension and stretching of the vertebral column; the whole of the trunk is projected in the same manner by the extension of the pelvis upon the thighs; the thighs by rising rapidly act in the same manner upon the pelvis; the legs push the thighs in their turn. From all those united powers there results such a force of projection, that the whole body is thrown upwards, and rises in proportion as the power is greater than the weight: it then returns to the ground, presenting the same phenomena as any other body which falls by its weight.

In the general spring which produces leaping, the muscular action has not everywhere the same intensity: it ought evidently to be greater in that part where the weight is most considerable: on this account the muscles that determine the motion of extension of the leg upon the foot are those that have the greatest energy, since they must raise the whole weight of the body.

These muscles present also the most favourable disposition; they are very strong, and they are inserted in a direction perpendicular to the lever which they move, the heel bone, and they act upon an arm of the lever of considerable length.

We must remark, that the vertical leap does not result from any direct impulse, but from one which is made up of the opposite impulses of the body and the inferior extremities, at the moment of leaping. In fact, the recovering of the head, of the vertebral column, and the pelvis, carries the trunk as much backwards as upwards; on the contrary, the extension of the thighs upon the tibia brings the trunk as much forwards as upwards. The contrary takes place in the motion of the leg, which tends to direct the trunk upwards and backwards: when the leap is vertical, the efforts which throw the body forward or backward neutralize each other; the effort upwards is the only one which takes effect.

If the leap is forward, the extension of the thigh upon the tibia predominates over the impulsion backwards, and the body is transported in the corresponding direction: if the leap is backward, the motion of extension of the vertebral column, and of the tibia upon the foot, is the greatest.

Length of bone in the inferior extremities is very favourable to leaping. The leap forward, by which we pass a greater space than in any other mode of leaping, is indebted for this advantage to the length of the thigh.

Sometimes we run a greater or less distance before leaping; we then take a *spring*, as it is called. The impulsion which the body acquires by this preliminary motion, materially adds to the force and extent of the leap.

The arms are not passive in jumping; they approach the body at the instant in which the articulations are bent; they separate from it, on the contrary, the instant the body quits the ground. The resistance which they present to the muscles that raise them, enables these muscles to exert a power upon the

trunk in drawing it upward, which contributes to the production of the leap. The arms are useful in this respect in proportion as they present a certain resistance to the muscles by which they are raised. The ancients had made this remark; they carried in their hands weights when they wished to exercise themselves in leaping. By previously balancing the arms we may also favour the production of the horizontal leap, in giving an impulsion forward or backward to the upper part of the trunk.

One of the lower limbs is sufficient to originate a leap, as when we hop; but it is easily understood that such a leap is necessarily of less extent than when both feet are employed. Sometimes we leap with the two feet joined, and parallel to each other; sometimes one of the feet is carried forward during the projection of the body: this foot then receives the weight of the body the instant it touches the ground.

No species of impulsion can be given to the body, at the instant of its rising, by the plane upon which it rests, unless this plane is very elastic, and joins its re-action to the effort of the muscles which determine the projectile motion of the body.

In general the ground gives no assistance to the leap, except by resisting the pressure of the foot. Every one knows that it is impossible to leap when the ground is soft, and gives way under the feet.

Of Running.—Running results from the combination of the step and leap; or rather it consists of a succession of leaps performed alternately by one limb, whilst the other is carried forward or backward, to be placed upon the ground, and produce the leap, as soon as the first has had time to be carried forward or backward, according as the running may take place in the one or the other direction. We can run with more or less rapidity; but in running there is always an instant in which the body is suspended in the air, by the impulse which is given to it by the limb which remains behind, if we run forward.

Running is distinguished by this character from rapid walking, in which the foot carried forward always touches the ground before that which is behind leaves it.

Of Swimming.—The human body is of a greater specific weight than water, consequently when placed in the midst of a mass of that liquid, it will tend to sink to the bottom; this

motion will be so much more easy as the surface it presents to the water is less. If, for example, the body is placed vertically, the feet below and the head above, it will go much quicker to the bottom than if it were placed horizontally on the surface of the liquid. Some individuals, however, have the faculty of rendering themselves specifically lighter than water, and therefore they remain on the surface without any effort. Their art consists in drawing a great quantity of air into the chest, the lightness of which counterbalances the tendency which the body has to sink in water.

Swimmers do not follow this method to support themselves upon the surface of the water; they are supported by the motions which their limbs perform; or the motions of the swimmer are intended either to support his body on the water, or to determine its progression. In either case the swimmer must so act upon the water that it may present a resistance sufficient to support his body: with this intention, it is necessary only to strike it quicker than it can escape, and to carry the action of the hands or the feet rapidly over a great many different points, because the resistance is in proportion to the mass of water that is displaced.

SECTION IV.

Of Physiognomical Expression.

The whole frame has its physiognomy, and manifests by its bearing what is passing within. There are two principles upon which the bodily gestures declare the nature of the present mental emotion, and of tho habitual train of thought or feeling. One of these is, that all mental affections dispose us to corresponding attitudes. It is true, indeed, that the most violent alone lead to any very decisive gesticulation; but all are naturally accompanied with a consistent and (as it would be termed on the stage) an appropriate action. The other results from the influence of habit on our muscular frame. Towards actions that are frequently indulged in, the muscles acquire a bias; so that, without reflection or design, we are disposed to fall into those gestures that our employments have rendered

habitual. The mechanic does not lay aside his wonted movements with his working dress; they recur when he would forget his trade, and betray his customary occupations.

If this is true of the general action of the frame, it is still more strikingly so when applied to the muscles of the face. Both the principles of physiognomical expression referred to equally find their application here. The passing feeling intelligibly lights up or clouds the countenance; the habitual current of thought stamps it with permanent expression. The joy or sorrow of a child no one can misconstrue. The concentrated and patient thought on the brow of Newton who can misinterpret? The difficulty which exists of reading men's thoughts in their countenances arises from their practised art to disguise what is passing in the mind.

But how do we read the thoughts of others in their features, or how interpret their expression of countenance, whether the true or a false one? I believe that the knowledge does not come directly to us, except in as far as it may have been previously acquired by experience; as a child only knows what is meant by a gesture of reproof, after it is associated in its mind with punishment. I conceive it to be indirectly through the imitative principle that we learn what is passing in other men's minds. There is an instinctive disposition in us to assume the character of the features on which we look; and whether we yield to the impulse or not, the transient approach to doing so awakes in us the mental state, with which that expression is associated in the mind of the person whom we look at. We attribute such thoughts to others, because the expression into which our countenance is disposed to fall, on looking into theirs, excites such a train of feeling in us.

There are various ways in which a physiognomist is liable to be misled. In some persons the features have a cast and bent towards a particular expression, without any corresponding character in the mind. If the muscles had so inclined the features, the physiognomical conclusion would have been right: as it is, in the case supposed, the shape of the features is an accident. The profoundest dissimulators probably have a pliancy of mind, which enables them perfectly to assume the character or the views, of their possessing which at the time they would persuade others. Every one, again, though he may obtain by physiognomy a knowledge of the present cast of

mind or feeling of the person he is watching, is liable to be misled by his own character, by his knowledge of what would be required to excite himself to such a mood, and to calculate more or less wide of the mark the various accidents of health, high or low spirits, or other circumstances, in determining the degree and even the kind of sentiment displayed.

The quantity of expression in any feature is determined by the variety of its motion: the variety of its motion, by the number of muscles attached to it. The eye and eyelids on the one hand, and the mouth on the other, have the greatest number of muscles, and the greatest range of expression. Of the two features, it is difficult to say which has most character. The eye, perhaps, displays more of temperament and humour, the mouth of reflection and thought.

There are some curious remarks by Dr. Wollaston, in a paper in the Philosophical Transactions, on the mode by which we judge of the direction of the eyes of others. Dr. Wollaston supposes, that our notion that a person is looking at us, depends not upon his eyes, but upon the general disposition of the other features. He adduces a drawing by Sir Thomas Lawrence, of the eyes and eyebrows, to which different features are adjusted in different fignres, and certainly each head appears to look a different way with the same eyes. Upon examining these figures, however, the reader will, I think, agree with me that the deception arises from their being out of drawing. The following observations will, I think, be found to contain the essence of this question.

1. We judge by immediate observation of the direction of the visual axis of one eye in a living person, or in a portrait. This is the more easily determined in the case of the human eye, through the circularity of the pupil, the *concentric* circles of the iris, and the extent of the white area in which these concentric circles are set. This distinctness of direction, so characteristic of the eye of man, may be one of the causes why the human eye has such power over animals.

2. We judge of the direction of the other eye by the same process by which we judge of the direction of the first, in looking either at a drawing, or at a living person. If the second corresponds with the first, it of course strengthens the impression received as to the direction of the first.

3. Whichever way the features are turned, if their direction is not incongruous with that of the eyes [and, except in

squinting or convulsions, in a living head it cannot be so], the correspondent action and expression of the face corroborate the impression derived from the direction of the visual axes.

4. If, as I believe to be the case in Dr. Wollaston's figures, the other features are actually incongruous with the direction of the eyes, if the *eyes*, and *eyebrows*, and *eyelids*, are drawn with one inclination, and the forehead and nose with another, then we are puzzled; and the same eyes which would look one way in a drawing, all parts of which should be correctly designed, seem to look a different way in the incorrect drawing. The eyes belong, in such a case, to a face looking one way, and the face belongs to eyes that would be looking another way; and our conclusions are puzzled—something as when we cross the fingers, and feel a single object double.

5. Finally, if we make a drawing of a head without eyes, and then put in one eye accordant with the rest of the features and turned towards the spectator, the unfinished portrait looks truly at us. If the other eye is then drawn, but as if turned away, or squinting, the picture ceases to appear to look at us. If, however, we cover the squinting eye, the picture again seems to look at us. Of course there is exactly the same difficulty in telling which way a living person who squints is looking, unless he covers the eye that is directed obliquely. We can tell [as in Dr. Wollaston's figures] which way one incongruous part is looking, and which way the other, when we observe them singly. When we look at both at once, we are puzzled, by striving to reconcile things that are irreconcilable, trying to make out to what common point features are turned, that are really turned different ways; and in this perplexity we lose for the time the true direction of both.

SECTION V.

Of the Mechanism of Breathing.

The thorax of a skeleton is a hollow conoïd, broad below, narrow above, where it is obliquely truncated: its axis is inclined obliquely upwards and backwards: it is composed of the dorsal vertebræ, the ribs, and sternum. The twelve dorsal vertebræ form a column so bent as to be concave forwards, and which, in reference to changes of figure in the chest, may be

considered as fixed. The twenty-four ribs are individually moveable upon the spine in every direction, but to a degree extremely limited. The seven uppermost on either side, or the true ribs, are let in by slips of cartilage into oval fossulæ along the side of the sternum, which they support. The five lower, or the false ribs, are attached each to that above. The ribs and sternum are slight and fragile bones. In composition they derive strength from their external convexity, and from their numerous and yielding joints.

An imaginary plane carried through the first dorsal vertebra, through both articular extremities of the first rib of either side, and through the upper part of the sternum, would slant obliquely downwards and forwards. By a movement of each first rib upon its spinal joint sufficient to raise the upper margin of the sternum to the height of the first dorsal vertebra, the imaginary plane would become horizontal. In man this motion of the first rib is very limited; but it is obvious, that in proportion as it takes place, the vertical distance of the sternum from the spine, or the depth of the chest, becomes increased. The six lower true ribs admitting of the same kind of motion upon their vertebral joints, contribute to raise and carry forward the middle and lower part of the sternum for the same purpose.

By this provision all the muscles of the trunk, the lower attachment of which is to the ribs, are rendered capable of increasing the depth of the chest, or its diameter from before backwards; and the opposite class of muscles, of diminishing the area of the chest in the same dimension.

All the ribs, but the first, admit of a limited degree of rotation upon their vertebral and sternal joints. Nature marks, even in the fœtal state, the limited degree of motion, which the first rib is intended to enjoy, by forming its cartilage of one piece with the sternum, to which the cartilages of the succeeding ribs are already articulated by moveable joints; and by disposing all its parts in one plane. If an oblique plane were imagined to pass through the four joints of any pair of ribs between the second and tenth inclusively, great part of the shafts and cartilages of the pair of ribs would fall below it. If the intermediate part of these ribs is raised towards the imaginary plane, by the rotation of each upon its sternal and vertebral joints, it is obvious that the transverse diameter or breadth of the chest becomes increased.

By this provision the same muscles which contribute to enlarge the depth of the thorax are rendered capable of adding to its breadth, and the same which diminish its area in the first dimension, are fitted to diminish it in the second.

The muscles which raise the ribs, are the serratus magnus, pectoralis major, pectoralis minor, and subclavius; the levatores costarum, the scaleni, and serratus posticus superior.

The muscles which depress the ribs are the external and internal oblique, the transversus, the rectus, and pyramidalis; the triangularis sterni, the quadratus lumborum, the longissimus dorsi, sacro-lumbalis, and serratus posticus inferior.

The chest is closed above by a fascia or layer of condensed cellular membrane, which extends across from the spine to the sternum, and from the first rib of one side to the opposite, and is perforated by the windpipe, by the œsophagus, by nerves, and by the great vessels. The intervals between the ribs are closed by the oblique fibres of the intercostal muscles, which in their action draw towards each other adjoining ribs, and are capable of contributing either to the enlargement or to the diminution of the area of the thorax.

The floor of the chest is formed by the diaphragm, or muscular partition, which separates it from the abdomen.

The diaphragm consists of three parts. 1. Of a central thin tendon of the shape of a trefoil leaf, of greater breadth than depth, which, although in a degree concave downwards, yet may be regarded as spread out horizontally at the level of the ninth dorsal vertebra, or of the lowest part of the fifth rib. 2. Of muscular fibres derived from the anterior and lateral margins of the central tendon, which slope downwards to be inserted into the ensiform cartilage and into the inner and lower part of the seven lowest ribs, and are called the greater muscle of the diaphragm. 3. Of other muscular fibres which descend from the posterior edge of the centrum tendinosum to the lumbar vertebræ, and are called the lesser muscle. The diaphragm gives height by its action to the cavity of the chest. In an ordinary inspiration, the lateral parts, or the greater muscle, alone sensibly descend.

Except during the deepest inspiration, the lungs do not reach lower than the sixth rib in front, and the eleventh dorsal vertebra behind; nor intermediately lower than the oblique line, which unites the points indicated. Below this level, to the

distance of an inch and a half from the margin of the chest, the diaphragm lies in contact with the ribs, or rather the pleura diaphragmatica with the pleura costalis. The diaphragm gives passage to different vessels and nerves; and it is remarkable, that while the œsophagus, the aorta, and thoracic duct pass through muscular apertures, the pressure of which they are calculated to resist or to profit by, the great ascending venous trunk passes through an opening in the central tendon, with the margin of which its substance is interwoven, so that the vein is perpetually held open by the tonic force of the greater and lesser muscle.

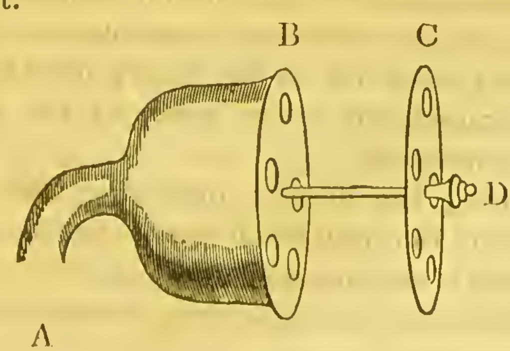
The abdominal muscles are the antagonists of the diaphragm, which upon becoming relaxed admits of being raised through the pressure of the abdominal muscles upon the bowels.

SECTION VI.

Of the Mechanism of Speech.

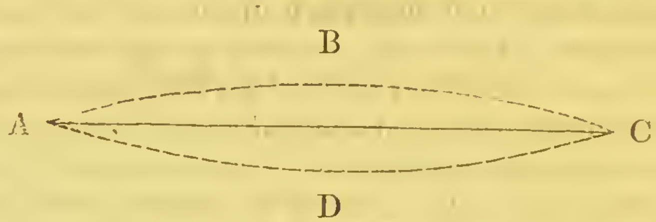
It has been already mentioned, that the physical cause of continued sound is a succession of impulses upon the auditory nerve. These impulses originate at greater or less distances from the organ of hearing, and are conveyed to it by the undulations of elastic media. Their origin again may be either repeated single beats, as when a stream of air is forced through apertures which are alternately opened and closed; or consecutive vibrations excited in an elastic substance by a single disturbance.

The simplest example of the first mode of producing continued sound is shown in an instrument invented by Cagniard de la Tour, called the syren. The subjoined figure represents this instrument.



It is supposed, that air [or water, if the instrument is placed under water] is impelled into a tube A, so as to keep a reservoir full, from which the fluid may issue by the holes in its surface B. Now if the disc C, having holes exactly corresponding to those in B, be pressed against B, and be made to revolve upon an axis D, it is evident that the holes in B will be alternately opened and shut. Each time that they are opened, there will be a jet of fluid which will strike the medium without audibly. By the velocity with which C is made to revolve, the frequency of the recurrence of these impulses may be regulated;—the frequency necessary to produce a continued sound may thus be ascertained, as well as the number of impulses by which a definite pitch is produced. The instrument is therefore a perfect tonometer.

The vibration of a harp-string presents an instance of the second mode adverted to of producing continued sound. If a tense chord, A C, be drawn to A B C, and let go, it returns



to A C, and through the motion it has acquired is carried to A D C. It is then brought back by its elasticity towards A B C, then returns towards A D C, and continues to vibrate, its excursions becoming at each vibration less in extent. Each excursion gives an impulse to the air, and the number of excursions in a given time determines the pitch of the sound.

The action of the bow of a violin upon the string may equally be illustrated by the preceding diagram; but, in this case, it is the action of the hairs of the bow that carries to B the string, which then escapes, and flies back to D. The continued pressure of the bow has the effect of sustaining the sound at a given loudness, or even of raising it, which else would die away with the diminishing excursions of the string.

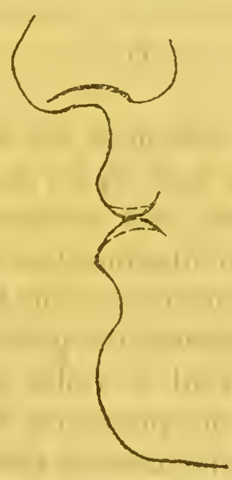
Suppose the string to be moved by the wind, as in the Æolian harp, its vibrations so produced may assist to explain the next instance which is to be mentioned.

If you blow through a tube of Indian rubber, or one formed of the stalk of grass, a sound is produced, as soon as you com-

press its sides at a part near the mouth with the finger and thumb. The figure subjoined represents part of the effect which

takes place. The narrowed portion of the tube through the pressure of the air blown into it becomes dilated (suppose to the dotted lines); it then closes, the sides coming together; again yields, and again closes. The alternate enlargement and contraction of the aperture is the source of the succession of impulses which cause the sound which is heard.

Or, to adduce a case that approximates still nearer to the action of the larynx; with a little practice any one may produce tones by blowing through the closed lips. The difficulty at first experienced consists in giving the lips the proper degree of tension; but when this difficulty has been overcome, musical sounds issue with the breath, produced by the alternate receding and approximation of the lips, in the manner shown by the adjoined diagram. The degree of pressure and tension of the lips determines the frequency with which the aperture, that the current of air forces, is opened and shut.



I have heard a performer, who had such perfect command of the lips, that he could by their means imitate any one of a variety of instruments, and thus play one part of a composition by the lips, at the same time that with the larynx [which likewise in him was wonderfully flexible], he produced the tones belonging to another part of the music. The mechanism employed in this instance is different from that used in whistling, the nature of which will be afterwards noticed.

Now the whole vocal mechanism consists of the following parts;—Of the lungs or bellows, capable of transmitting, by means of the connecting windpipe, a current of air through an apparatus called the larynx; the air having subsequently to pass through a variable cavity, consisting of the pharynx, mouth, and nose.

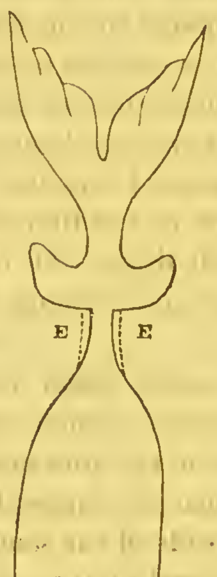
Variable cavity.

Larynx.

Windpipe.

Lungs or bellows.

But the larynx, which is the part of the mechanism in which it is ascertained that the vocal sounds originate, contains parts which admit of being compared with the lips, and like the latter, may be placed in different degrees of tension, allowing the air to pass intermittently, with a frequency varying as the tension.



The figure here introduced represents a transverse and vertical section of the cavity of the larynx: the letters [E E] show the position and outline of parts comparable to the lips in the preceding instance. They are called the vocal ligaments. Their alternate vibrations towards and from the dotted lines under the pressure of the issuing air, alternately opening and closing the passage, are essential to the production of those impulses upon which the sounds of the voice depend.

Let me now proceed to explain by what means the vocal ligaments are placed in a condition to cause sound.

By far the most valuable account of the mechanism of the human larynx, which has been published, is that given by Mr. Willis in the Cambridge Philosophical Transactions for 1832, from which I borrow the second figure of the two which follow in page 367.

The reader is aware that upon the top of the windpipe, which is a pile of cartilaginous rings, serving to keep the passage from the lungs always open, a stout annulus is placed, called the cricoïd cartilage: it is marked B in the two figures over-leaf.

Upon the upper surface of the back part of the cricoïd, are placed two small pyramidal cartilages, called the arytænoïds: they are marked C, in the following figures. Their bases are hollowed, and they have a sliding motion in every sense upon and in front of the border of the cricoïd, to which they are tied by the strong ligaments marked H.

The thyreoïd or scutiform cartilage [A], bent at its middle to a right angle, encloses and protects the cricoïd and the arytænoïds. It is articulated to the sides of the former by two processes upon which it is capable of being moved in a rotatory motion forwards and downwards, or backwards and upwards.

The inferior laryngeal or vocal ligaments [F F], extend from the base of either arytænoïd cartilage to meet at a common insertion in the fore part of the thyreoïd. They are formed of fibres possessing a high degree of elasticity, but not much extensibility. The opening between them is called the rima glottidis.

Above and parallel to the lower vocal ligaments two other ligaments [G] are situated, which extend from the anterior edge of the arytænoïds to the junction of the two plates of the thyreoïd: these are called the upper ligaments of the glottis. They contain a few threads of the same substance as the lower ligaments, but their general texture is more extensible, and of a looser fabric. The oval opening between the upper ligament of one side of the glottis and the lower leads into a large flattened triangular chamber, which is called the ventricle of the larynx or saccalus laryngis.

These parts are crowned with two pairs of little cartilages, which are called cornua.

The lesser horn [D] is a small cartilage of the size of a millet seed or less, which is superimposed on the arytænoid, and joined to it by ligamentous fibres.

The greater horn [E] is a portion of a small cylinder of a loose cartilaginous structure, the lower end of which adheres to the posterior part of the upper ligament of the glottis; the upper end, whieh is rounded, is directed slightly backwards and outwards, as well as upwards.

The epiglottis is a pyriform flap of elastie cartilage whieh is attached to the thyreoïd, just above the attachments of the upper laryngeal ligaments. Its natural direction is vertical, and to this its elasticity brings it back, after it has been depressed to eover the entranee into the windpipe during deglutition.

The larynx is lined with mueous membrane, continuous on the one hand with that of the pharynx, on the other with the mueous lining of the traehea. The mueous membrane at the summit of the larynx extends in a strong fold from either lesser horn to the side of the epiglottis. The two folds are called the lips of the glottis. The greater horns hold these folds outward and rather backward, having the offiee of keeping the opening between the lips of the glottis or upper orifice of the larynx more patulous than it else would be.

Of the two figures in the opposite page, the uppermost represents the inner surface of the right half of the larynx, without the epiglottis or lining membrane or interior muscles.

The second figure represents the cartilages and museles of the larynx, omitting the cornua and the epiglottis, as seen after dissection from above.

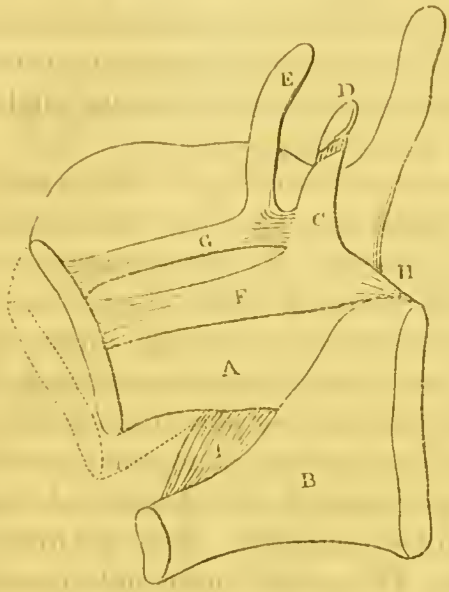
The muscles are designated by *numbers*.

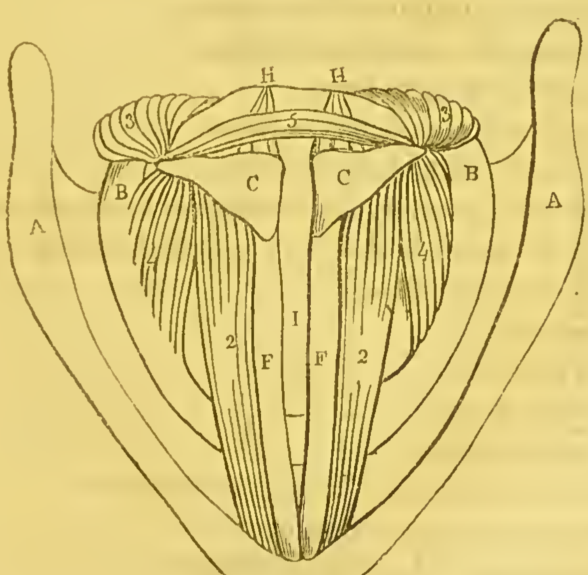
1. Represents the crico-thyreoïdeus.
2. The thyreo-arytænoïdeus.
3. The crico-arytænoïdeus postieus.
4. The erieo-arytænoïdeus lateralis.
5. Half of the arytænoïdeus transversus, and of the obliqui.

The *letters* in one or both of the opposite figures represent,

A. The thyreoïd eartilage.
B. The crieoïd.
C. The arytænoïd.
D. The lesser horn.
E. The greater horn.
F. The vocal or inferior laryngeal ligament.
G. The upper laryngeal ligament.

Page 368 contains Mr. Willis's tabular view of the action of the muscles of the larynx.


E
D
C
G
H
F
A
B


H
H
3
5
3
B
C
C
B
A
A
4
4
I
2
F
F
2

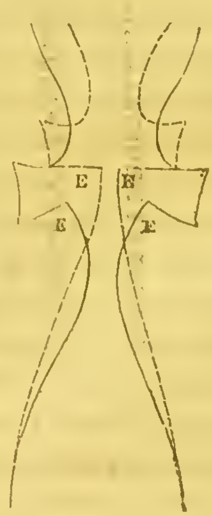
ANTAGONISTS.	Crico-thyreoïdei	Stretch the vocal ligaments.		Govern the pitch of the notes.
	Thyreo-arytænoïdei	Relax the vocal ligaments, and place them in the vocalizing position.		
ANTAGONISTS.	Crico-arytænoïdei Postici	Open the glottis.		Govern the aperture of the glottis.
	Crico-arytænoïdei Laterales	Press together the front portion of the arytænoïds.	Together close the glottis.	
	Arytænoïdei Transversus et Obliqui	Press together the hinder portion of the arytænoïds.		

From this enumeration of the muscles of the larynx and of their uses, it is evident that ample means exist of opening and closing the rima glottidis, and of increasing and diminishing the tension of the vocal ligaments. Let us proceed to inquire to what extent these means are employed in ordinary vocalization.

Mr. Willis supposes that two conditions of the larynx are necessary for vocalizing: one, a certain degree of tension of the lower ligaments of the glottis; the other, their approximation with their edges disposed in a special manner.

"The most generally received opinion," Mr. Willis observes, "and that which appears to me to be borne out by a careful investigation of the structure of the larynx, is, that the current of air from the lungs excites these ligaments to vibration, and so produces the sounds of the voice. Hence they are denominated the *vocal ligaments.* I shall not now proceed," he adds, "to a more minute examination of the precise nature of this vibration, and of the larynx generally, than appears to have been hitherto attempted. Assuming that the source of the notes of the voice is to be found in the vibrations of a pair of membranous elastic edges, between which a current of air is allowed to pass, I shall endeavour to show under what conditions such elastic edges must be presented to a current of air, in order that it may elicit from them the required vibrations."

The essential condition, Mr. Willis proceeds to show by experiment, is, that the parts of the two opposed membranes near their edges should be rendered parallel. Comparing with the disposition of membranes found requisite in these experiments that of the vocal ligaments, he supposes that the latter will not speak, unless a corresponding change, *independent of and superadded to their tension,* is produced in their relative position. The adjoined figures show what Mr. Willis considers the ordinary position, and what the vocalizing position, of the lower laryngeal ligaments [E E]. The former is shown by the continued line, the latter by the interrupted line.



Mr. Willis adduces the following observations in proof of his opinion, that some change in the relative position of the vocal

ligaments is necessary, independently of their tension, to make them sound. If the finger is placed upon the membrane which intervenes between the thyreoïd and cricoïd cartilages, their approximation or increased remoteness may be felt. Now their approximation being produced by the action of the crico-thyreoïd muscles involves a certain tension of the vocal ligaments. But it is possible by an effort to keep these cartilages approximated, while something is still wanting in the internal arrangement of the larynx to fit it for the production of sound. When the thyreoïd and cricoïd are thus approximated, and the ligaments are therefore in a state of tension, air may be impelled through the larynx, without sound *necessarily* following: — the ligaments have still, Mr. Willis concludes, to be placed in the vocalizing position. For an account of the muscular actions by which this is supposed to be accomplished, I refer the reader to Mr. Willis's original paper.

The observation narrated certainly proves that the vocal ligaments have equal tension during expiration, without or with a vocal sound. But it goes no further: and it leaves us free to conjecture, that the change which allows the ligaments not to vibrate in the former case, may be other than Mr. Willis supposes. I think it far from improbable, that the difference in the state of the ligaments in the two cases may be this; — for vocalization, the ligaments may acquire a definite tension joined with contact for their whole length: to allow air to pass without producing a laryngeal sound, *the same tension being at the same time maintained,* the ligaments may require to be drawn apart, and the rima glottidis to be opened at its posterior part.

The reason which weighs with me for preferring this solution of the fact adduced to Mr. Willis's is, that I cannot conceive it possible to place the vocal ligaments on the stretch without converting the outline of each of them into that assumed in the vocalizing position of our author. It will be evident to the reader, that so far from impugning Mr. Willis's analogical experiments, I am adopting an hypothesis which is perfectly consistent with them. I believe that the vocal ligaments, when tended and approximated, cannot be in any other position than that which Mr. Willis supposes to be peculiar to the time of vocalizing. I suppose, that, for the production of laryngeal sounds and for closing the glottis, there is one common position of the vocal ligaments, that position being contact for the

whole length of their internal aspect, accompanied with tension; the difference between the states of the parts in vocalizing and in closure of the glottis being the same as between the states of the lips when rendered tense to form musical sounds in the manner before described, and when compressed so as to oppose the escape of air during action of the respiratory muscles. To shut either the lips or the larynx, or to convert the vocalizing position of either into one of entire closure, additional lateral pressure, or pressure acting transversely to their linear aperture, must be put on.

The grounds upon which I think the preceding modification of Mr. Willis's hypothesis maintainable are the following:

A patient was under my care, in the Middlesex Hospital, who lived many weeks after having cut into the pharynx in an attempt to destroy himself. The wound was horizontal, and passed backwards over the upper border of the thyreoïd cartilage, severing the epiglottis near its attachment to the latter. There was a period during the progress of this case when the patient was collected and cheerful, and anticipated his recovery. I took advantage of the opportunity, to observe the motions of the parts of the larynx which were exposed. They presented, under different circumstances, the appearances shown in the following figures.

1

2

The line, which forms the upper boundary of these figures, represents the front of the upper and posterior part of the glottis, as it was seen upon looking from above into the wound. When the patient breathed naturally, the parts had the disposition shown in figure 1. At first I thought, when observing these phenomena, that the two prominences marked F were the arytænoïd cartilages; but, upon more careful examination, I found that they were the cartilages which I have figured as the greater horns of the larynx in a former diagram in this section. They had before been very imperfectly described under the name of sesamoïd bodies.

When the patient, at my request, closed the glottis, making an effort of straining, the parts came into the position given in

figure 2. The greater horns were now approximated, and the line of contact of the arytænoïds was besides distinctly discernible.

The patient was then desired to utter a sound. On his doing so, no further visible change took place in the position of the parts. These observations I repeated many days in succession. The position of the parts during vocalizing was precisely the same as during the closure of the glottis. When the patient alternated these actions, passing directly from the one to the other, no visible change in the location of the parts took place.

But the parts seen in these observations were so near to and so connected with the vocal ligaments, as to render any change in the disposition of the latter impossible without a visible change in the disposition of the former. As therefore no change was seen in the parts exposed, when the transition was made from closure to vocalizing and the reverse, it may be presumed that none took place in the collocation of the ligaments. It is only necessary further to remark, that the lower or vocal ligaments must have been in contact during the closure of the larynx, otherwise there would have been no impediment to the breath: for there was nothing in the appearance of the parts to show that the upper ligaments were brought into contact. The vocal ligaments must therefore have been in [intermitting] contact during vocalization.

If we are now acquainted with the principal elements in the production of sound in the larynx, much nevertheless remains to be explained, which can only be satisfactorily elucidated through new series of physical experiments. The uses of the sacculi, of the upper ligaments of the glottis, and of the epiglottis, are subjects of this nature.

The theory of Savart converted the ventricles of the larynx into a bird-call. He supposed, that the two pairs of ligaments, with the intermediate chamber of the ventricles, form an apparatus analogous to that instrument. It is thus that the lips are made to whistle,—by combining them with a chamber. In whistling, we form a bird-call at the mouth, of which one aperture is that at the lips: the other is made by the approximation of the tip of the tongue to the palate, and the chamber is the space between. The shrillness of sound which naturally results from such an instrument, Savart experimentally showed would be obviated by the walls of the cavity being

moist and relaxed. Nor can it be doubted, that the ventricles of the larynx with the upper ligaments must play an important part in vocalization. What they contribute, however, and how their effects combine with those of the vocal ligaments, may be considered as at present unknown.

There is another part in the vocal apparatus, the influence of which requires to be estimated: this is the trachea. Mr. Wheatstone proposes the following theory of its influenee.

Such a vibrating apparatus as the ligaments of the glottis have been shown to compose, is by itself capable, from the varying tension of those ligaments, of producing all those sounds of which we find the voice to be capable. But the intervention of a tube between the lungs and the larynx, must necessarily exercise an important influence on the voice, though it has never yet been taken into consideration. For, if we unite such an apparatus, or a free reed, which may serve as a substitute for it, with a tube (supposing it for the moment fixed to a determinate degree of pitch), it is found, that, unless the column of air in the tube is of such a length as to be separately capable of producing the same number of vibrations, the sound cannot be obtained in its greatest force and purity, and that when the tube is half this length, the discordance between the tube and the reed is so great, as to prevent the production of the sound: between these limits, the sound is intermediate in intensity and quality. This influence of the tube is by experiment found to be the same, whether the tube is placed after the reed, as in several wind instruments, or before it, as in the vocal organ. We will now suppose the tube to be unalterable in its length, and the reed necessarily to undergo all its varying modifications of pitch: the sounds, instead of being of even quality, will be irregular in intensity, and require different degrees of effort to produce them; while, in some parts of the scale, they will be totally extinguished. All this may be prevented, and the utmost regularity obtained, by shortening the tube, in proportion as the vibrations of the reed increase in frequency. The trachea is obviously incapable of changing its length within limits sufficiently considerable to serve this purpose: but Savart's experiments have shown, that a tube of constant length may be made to produce a great range of sounds, by making it of elastic sides susceptible of variable tension. The analogy between such a tube and the trachea is perfect.

One souree of giving increased tension to the windpipe is the action of the transverse museular fibres which bind the ends of its cartilages together. A second is the elevation of the larynx, which accompanies to so remarkable an extent the elevation of the piteh of the voiee.

Another relation of a tube or chamber to a free reed, or other generator of sound connected with it, has been illustrated by Mr. Wheatstone, and applied by him to the explanation of a very remarkable vocal phenomenon recently exhibited.

This relation Mr. Wheatstone determined, in accounting for the sounds produced in playing on the Jews'-harp. In this performance, two sounds are heard; one, a bass sound, or drone, which goes on without changing; the other, a succession of higher notes, which are varied at the pleasure of the performer. The means which he employs are altering the form and size of the cavity of the mouth. Every volume of air, like every string, *when made to vibrate*, yields a definite note, or vibrates with a definite frequency. Now if to a vibrating reed a chamber is adapted containing a volume of air, which is calculated to vibrate with the same frequency as the reed, that volume of air will be thrown into vibration when the reed vibrates, and the effect of its vibration will be to reinforce the sound of the reed. If, however, the volume of air is calculated to vibrate something faster or slower than the reed, it is not thrown into vibration by the reed, but remains silent. But if it happen to be exactly such as will vibrate multiples [in frequency] of the vibrations of the reed, then it is thrown into vibration by the reed, and a second note is heard, higher of course than the note of the reed. The art of one who plays on the Jews'-harp consists in so altering the cavities of the fauces as to present a suceession of volumes of air, whieh are calculated to vibrate the different multiples of the bass sound required.

The exhibition to which I have referred was that by Mr. Richmond. When listening to him, you seemed to hear a musical snuff-box: but besides the melody, you heard a bass sound. The bass sound was laryngeal: the higher notes were multiples of that sound obtained on the principle just explained, by altering the size and shape of the fauees. The performance is susceptible of infinite eompass, as the artist, if he happen to acquire a note that is not a multiple of the first bass sound, is able at will to substitute another bass.

As the pitch of vocal sounds depends upon the frequency of the vibrations of the vocal ligaments, their loudness is determined by the extent of the excursions which the latter make in vibrating. The difference between the voices of men, and those of women and boys, results from the smaller larynx and shorter vocal cords of the latter.

The conditions which give different qualities of voice are not known. The falsetto voice, Mr. Willis supposes, may be produced by the shortening of the lower vocal ligaments: Mr. Wheatstone's explanation is the following. Suppose the same sound to be produced by the ordinary voice and the falsetto. The ligaments of the glottis vibrating in the same manner in both cases, the difference may be this. For the ordinary sound the column of air in the trachea may vibrate entire; for the falsetto the column of air may assume an harmonic subdivision.

The range of the voice seldom exceeds two octaves and a half. Dr. Bennati affirms, however, that the compass of his own voice extended to three octaves. He mentions as an unexpected effect of removing part of the tonsils, that he has found the operation to be followed by the raising of the voice half an octave, without altering its compass. I suppose that this effect, if correctly observed, results from the cicatrix stretching the lining of the larynx, and thus giving increased tension to its inner surface.

When vocal sounds have been formed in the larynx, they have to receive articulation from the shape of the cavities through which the air has yet to pass.

The elementary articulate sounds in a language constitute its alphabet. They are divided into vowels and consonants. The former are produced when the passage of the air through the fauces is uninterrupted, the fauces being only more or less narrowed. They differ from each other in requiring a different elevation of the tongue, or contraction of the lips. Consonants are produced when the breath or voice in its passage through the cavities anterior to the larynx is temporarily interrupted by the complete or incomplete obstruction of some part of the channel.

M. Deleau made the following experiment, demonstrating that the articulation of vocal sounds takes place in the fauces. He introduced through the nostrils into the pharynx

a flexible tube, and impelled air through it into the fauces: then closing the larynx, he threw the fauces into the different positions requisite for producing articulate sounds, when the air impelled from the gum bottle became an audible whisper. Dr. Deleau repeated this experiment, allowing at the same time laryngeal sounds to pass into the fauces, when each articulated letter was heard double, in a voice at once and in a whisper.

Various attempts have been made to analyse and to produce by instruments the phenomena of articulate speech.

And, first, of the mechanism of vowel sounds.

Kratzenstein found, that, by using little tubes of different shapes adapted to an instrument that could produce sound, he could determine different vowel tones.

De Kempelen produced vowel sounds by means of an Indian rubber bell similarly adapted, the shape and size of which he altered by the hand.

But Mr. Willis's recent investigations are the most satisfactory. Mr. Willis attached to a free reed, a tube, which was capable, if immediately excited, of producing a determinate note. By altering the length of this tube, the original sound was made to assume the character of different vowels; evincing, that the vowel quality added to a note is the mere co-existence of a determinate musical sound.

The changes which take place in the human fauces, more resemble those which De Kempelen employed.

The adjoined diagram displays the position of the fauces requisite for pronouncing *au*, *ā*, *ee*. The position for *o*, and *oo*, is obtained by placing the fauces in the position for *au*, and then approximating the lips.

The consonantal sounds which we employ admit of being divided in the following manner.

There are some which may be rendered audible without a vowel sound. This is the case with *p, t, k, h, f, th, sh, s*. They may be termed aspirates. Others, again, without any appreciable difference in the shape of the fauces from the form required for several of the preceding to which they are allied, are not heard without a vowel sound. They may be termed sonants.

Again, for the utterance of the greater number of sounds, the soft palate is raised, and the passage of the air through the nostrils obstructed. By allowing the air to pass through the nostrils, a peculiar character is given to the articulation, and nasal letters are produced.

Consonantal sounds, again, are divided into continuous and explosive.

Continuous consonants are obtained, when the breath or voice passes through this cavity, interrupted by the narrowing of some part of the passage.

Explosive consonants are heard, when the breath or voice, passing through the mouth, is suddenly impeded by the entire closing of some part of the passage, or is allowed to burst out by the sudden opening of the same.

The following scheme contains the philosophical arrangement of consonantal sounds given by Mr. Wheatstone.

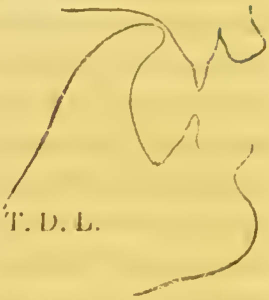
Aspirates.	Sonants.	Nasal.	
pe	be	me	labial.
te	de	ne	dental.
ke	ghe	ng	palatal.

Explosive sounds.

he	
fe	ve
the	dhe
she	je
se	ze
hle	le
hre	re

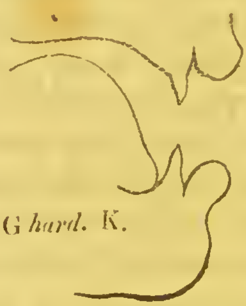
Continuous sounds.

The opposite diagrams display the position of the tongue and lips in the pronunciation of different consonants. The reader, if he is sufficiently interested in the subject, may, by referring to them, easily detect in his own articulation the motions of the tongue and lips by which the different sounds are determined. There are several curious applications of this study. It is possible to form an apparatus capable of articulating each letter. De Kempelen succeeded in constructing a speaking machine, which was capable of uttering entire phrases; some of which were—"Vous êtes mon ami—je vous aime de tout mon cœur—Leopoldus secundus—Romanorum imperator," &c. —De Kempelen published a detailed account of the construction of this instrument, at Vienna, in 1791. Mr. Wheatstone has reconstructed this instrument from De Kempelen's description; and I have heard it articulate the words mamma—papa—thumb—rum—summer—with great precision.



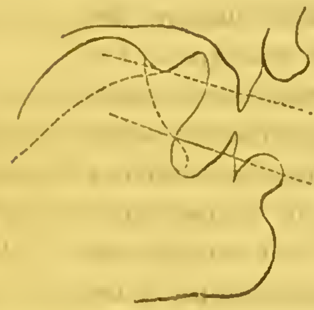
T. D. L.

F. V.



G *hard.* K.

The Italian and the Spanish languages, derived from the Latin, are softer to the ear than that language. Let me show, by an example, that they are actually softer, or require less effort, in the pronunciation. The Latin word *clamare*, becomes in Spanish *llamar*, in Italian *chiamare;* that is to say, of the two consonants which begin the word, the Italians drop one, the Spaniards the other. In the following diagram, the continued line shows the double and forced elevation of the root and apex of the tongue necessary for the simultaneous production of *c* and *l:* the two dotted lines show, that in the softer languages of Spain and Italy half the effort only is required for either. *Plenus, pieno, lleno,* are parallel instances.



Many persons have an imperfect articulation of different letters. The letter R is pronounced by several with the uvula. I have no doubt that its proper articulation might be acquired by any one, who understood clearly that it is to be performed by raising the tip of the tongue to the roof of the mouth, and allowing it to vibrate in the current of air.

One cause of stammering is a physical difficulty of articulating certain letters. One means, therefore, calculated to remove this defect is to study carefully the mode of pronouncing the difficult letters, to master exactly the mechanism of their articulation, and to practise their pronunciation repeatedly, slowly, and analytically.

The other rules to be followed by stammering persons are, to speak always with a full chest, to speak slowly, to pause the instant the hesitation begins, and, after waiting four or five seconds, to make collectedly a second attempt. It must be evidently useful to acquire by the habit of composition facility and variety of expression. In the worst spasm of the glottis occurring to a stammering person, he will often find the difficulty yield upon attempting a simple vowel sound, after which any other letter will follow easily.

One of the most remarkable facts regarding articulate speech is, that it may take place during inspiration. In that case the breath drawn through the fauces is first cut into letters, and subsequently receives a tone in its passage through the larynx. It appears probable that ventriloquists occasionally avail themselves of this artifice to diversify the character of their voice. In general, however, ventriloquists speak during expiration; and their art depends upon the flexibility of organ and correctness of ear, through which they modulate common tones to the character which they would take in the situation, from which the imaginary person in the dialogue is supposed to speak.

There are other sounds, the production of which I may take this opportunity of explaining.

Coughing and hiccupping are produced by the passage of air through the larynx upon its being suddenly opened. But the direction of the current of air is reversed in the two cases: coughing is an explosive expiration, hiccup an explosive inspiration.

In coughing, as in common utterance, the soft palate is raised, and the posterior entrance into the nostrils stopped. Sneezing takes place when the soft palate is lowered: it is, therefore, a nasal cough.

Laughter is exactly explained by the letters in which it is commonly expressed — *haw, haw, haw; he, he, he* — a more or less broad articulation of aspirated vowels.

With snoring, the larynx has nothing to do. The principal sound occurs during inspiration; and that, as well as the weaker expiratory snore, is produced by the fluttering of the uvula and of the edge of the velum pendulum palati in the current of air.

The mechanism which closes the aperture of the larynx is called into action on other occasions, besides the production of vocal sounds. If the most curious use of the larynx is the production of the voice, its most important office is the protection of the lungs. With its numerous muscles and quick sensibility, the larynx is placed as a guard at the summit of the windpipe, to admit indeed the entrance of the salubrious air, but to obstruct the passage of every thing that would prove noxious.

The double office of the larynx is strikingly illustrated, when we extend our researches into comparative anatomy.

In the cetaceous mammalia, which are dumb, we find a respiratory larynx alone. The windpipe terminates in a contractile circular aperture: and this opens, not at the root of the tongue, but is prolonged as a pipe far towards the nostrils, completely out of the way of the food.

In birds, on the other hand, in some of which the vocal function is so finely perfected, there is of course a larynx for sound, as well as a larynx for closing the windpipe; but they form two separate organs. The latter, an apparatus of the simplest construction, is placed at the top of the windpipe; the former,

highly complicated, is situated in the chest at the bifurcation of the trachea.

Now, in man, and in animals cast in the same type, there are two nerves distributed to their single larynx. One, the upper laryngeal nerve, has most to do with closing the larynx. The other, the recurrent, is found, by the experiment of dividing it, to have the most influence in the production of vocal sounds. The upper is given off from the pneumo-gastric, close upon the larynx. The recurrent is not given off till the pneumo-gastric has reached the chest, and then has to make a long course backward to the throat. This lengthened and circuitous course of the recurrent is a common theme of wonder in the anatomy of the nerves. I think its purpose is explained by referring to the vocal organ of birds. In birds, there are two nerves likewise on each side. The upper corresponds exactly with the upper laryngeal of man; it is the nerve to close the larynx of deglutition. The lower nerve corresponds with our recurrent: it is given off in the chest, and then it finds at once its destination. It is not *recurrent*, for the vocal larynx is not behind it. The human inferior laryngeal nerve is doubtless given off in the chest for the preservation of unity of the type of construction of mammalia and birds: it is recurrent, because the position of the human vocal larynx is above it.

But to recur to the means by which the passage through the larynx is closed. Mr. Willis has very ingeniously conjectured, that the closure takes place through the inflation of the ventricles from below, when the ligaments have been approximated, and an expiration is attempted. In the simple upper larynx, however, of birds, there are no ventricles: in their case, the closure of the glottis must certainly be produced by the close linear apposition of two membranous edges in a state of tension, and in exact contact. An objection was likewise suggested to me by Mr. Wheatstone, which of itself appears fatal to Mr. Willis's hypothesis;—we can close the larynx as well during inspiration as during expiration.

In the case of a patient in the Middlesex Hospital, to which I have already referred, I could look into the upper part of the larynx, and observe what took place when he voluntarily closed the passage through it. The appearance which the parts presented is exactly that delineated in the lower fig. 2, p. 371: it was, as I have already mentioned, identical with that observed

during vocalization. The lips of the glottis, or the reflection of membrane from the greater horns of the larynx to the epiglottis, formed an open funnel as before; the arytænoïds were indeed closely pressed together, but there was no appearance of complete closure of the passage above the vocal ligaments.

We must, I think, conclude, that the larynx is closed by the linear apposition of the inferior ligaments of the glottis, pressed together by the action of the arytænoïdei postici and transversus, in concert with that of the thyreo-arytænoïds and crico-thyreoïds.

Whatever may be the exact nature of this provision, its application is no less varied than it is important. Without it, the next meal would be fatal: without it, we should be unable to make a single muscular effort, in which the upper part of the frame takes a share.

M. Magendie, I believe, first made the observation, that the epiglottis is not the protector of the larynx against the passage of food into the windpipe during deglutition. He found, that that part might be removed from dogs, and that they retained perfectly the power of swallowing: while, on the other hand, the epiglottis being left entire, if the upper laryngeal nerves were divided, the attempt to swallow invariably brought on fits of choaking from the food finding its way down the windpipe.

In the case of attempted suicide last referred to, the epiglottis was cut through: yet the patient, in two or three days after the injury, swallowed easily, and without the least irritation of the larynx; although, so free was the opening in the throat, that some of the fluid swallowed always ran out at the wound.

In attempts at breathing, when the medium inspired is highly noxious, the effect of the closure of the larynx is no less admirable and perfect. When an animal is immersed in carbonic acid, it strives to inspire: but no particle of the gas can it draw with the whole force of its inspiratory muscles through the glottis, which has closed upon the contact of the hurtful agent. The same happens in submersion under water, or even under quicksilver. The protection, in these instances, is derived from the close consent between the sentient mucous surface of the larynx and its muscles.

A frequent kind of disorder in parts thus endowed is an increased susceptibility of the sentient surface, and a liability

to spasmodic action in the adjacent muscles, whose office it is to act from impressions received upon the former. Thus in the urethra, a morbidly sensible state of a part of the mucous membrane produces spasmodic stricture, or a continued contraction of the posterior fibres of the ejaculator. In the present instance the consequences are more fatal, inasmuch as the function impaired is more immediately important to life. An ulcer within the larynx is therefore a very serious disease. When this complaint exists, the whole surface of the larynx in time is rendered acutely sensible; the air passing over it is now an irritant; the fibres which close the opening of the larynx forcibly contract: the patient cannot draw his breath, and is threatened with instant suffocation. In hydrophobia, again, the portentous symptom, whence the name of the disease is derived, springs from the same cause. The surface of the larynx is preternaturally sensible (or is the principal seat of that morbid sensibility which is generally shared by every sentient organ in this disease); the passage of food, of liquid especially, the contact of which is more perfect than that of solid food, excites a spasm which threatens suffocation; and even if swallowing is not attempted, a paroxysm threatening suffocation takes place at intervals, either from the mere contact of the air passing over the sensible surface of the larynx, or in consequence of some sudden impression being made on another organ.

It deserves to be remarked, that whenever suffocation is threatened by a spasm upon the glottis, *that* particular symptom admits of relief by opening the windpipe; but no doubt in many instances, and hydrophobia is possibly one of them, the original disease would not prove the less rapidly fatal, were the spasm upon the larynx thus remedied *.

We may wonder that muscular fasciculi so slight as those of the larynx, however advantageously placed, should be capable of counteracting the efforts of the diaphragm and other muscles of inspiration. But they are found to be no less

* In dogs affected with hydrophobia, this operation is useless. I have had the means of trying this experiment, as well as several others, through the kindness and with the assistance of Mr. Youatt, who is zealous in every inquiry which tends to throw light upon this formidable disease.

efficient against the muscles of expiration. It was shown satisfactorily, by the experiments of M. Bourdon, that an animal can neither leap nor swim, if it be made to breathe through a tube introduced into the trachea. In the muscular fibres which close the larynx, Nature has provided the means of rendering the pliant walls of the thorax immoveable, so that the muscles which arise from the ribs may have a fixed point to act from. It is to be borne in mind, however, that the walls of the thorax admit of being moved, when the larynx is closed, if the motion be such as not to alter the capacity of the internal area of the chest. Thus in vomiting, at the time when the larynx is most firmly shut, the ribs sensibly descend; but they descend simultaneously with the diaphragm. If by descending they narrow the chest, the diaphragm by descending proportionably increases its height. Of the two motions, that of the diaphragm on this occasion is the important one; the pressure made by its descent forces out the contents of the stomach. The ribs only descend to allow the diaphragm to descend. It is equally possible, on the other hand, after shutting the glottis, to expand the chest, making the diaphragm and liver higher within the ribs.

CHAPTER XII.

OF GENERATION.

Generation is the production of a living being. Generation has been divided into true and equivocal. In the former, the living being is produced by separation from another within, or upon, which it grew. In the latter, it is supposed that vital existence begins during the dissolution of organized matter; — if a part of a dead animal or vegetable body is macerated for a few days in water, the water is found to teem with infusorial animalculæ. No decisive evidence has, however, been adduced to prove that the animalculæ of infusions are produced by chemical action, and are not the development of germs of their kind, which were previously contained in the organized texture.

True generation, again, presents several varieties. The simplest form is the spontaneous division of one living being into two. This extraordinary process has already been described as it occurs in the naïs [see page 9]. Plants, in general, are susceptible of propagation in this manner, if one part is *artificially* separated from the rest.

Opposed to the preceding form of reproduction, is growth from seeds or eggs, or the formation of germs, which under favourable circumstances are capable of gradually expanding into the character and dimensions of the parent. Reproduction of this kind presents several varieties. There may be one organ in the parent, by which the germ is at once formed and perfected. It is supposed, that the spore of fungi is thus produced. Or there may be, in one individual, two organs; one in which the seed is formed, another by the influence of which the seed is fertilized. This happens in monœcious plants. A remarkable variety of this mode of generation is, when one individual has both organs, yet the concurrence of two indi-

viduals is requisite for impregnation, which is reciprocal. This singular phenomenon occurs in snails.

Finally, the fertilizing organ may be exclusively found in one individual of the species, while the organ for producing the germ is met with in another. Then the distinction of sexes arises, and the beings are male and female.

The extensive subject of the reproduction of the species requires to be treated under three heads: the first describing the difference of the sexes, and the conditions necessary to impregnation; the second, the development of the ovum; the third, the source of the nourishment of the embryo, and the mode of its connection with the uterus.

SECTION I.

Of the difference of the Sexes, and of Impregnation.

The sexual parts, in the female, consist of the vagina, which is the organ of coition; of the ovaries, in which the germ is produced, and in which it is probably fertilized; of the uterus, to which it is transported from the ovaries by the Fallopian tubes, in which it is brought to maturity, and by the action of which it is born; of the mammæ, which supply the food of the infant for a long period after birth.

The sexual parts in the male are the testes, the vesiculæ seminales, the prostate gland, the penis.

The ovaries, which form the essential part of the female organs, are two flattened oval capsules, that are lodged in the fold of the peritoneum, which forms the broad ligaments of the uterus. They contain a loose succulent texture, in which there are several cysts, termed Graaffian vesicles, filled with a transparent liquid: their number is from fifteen to twenty; they are of every size up to the largest, which is commonly about four lines in its long diameter. At an early age the surface of the ovaries is smooth; after puberty it gradually becomes marked with numerous scars or cicatrices, as the Graaffian vesicles successively burst, and are filled up, and contract. The ovaries are supplied with blood by the spermatic arteries, with nerves by the spermatic plexuses: on their removal, the sexual passion is extinguished.

The uterus is a hollow fleshy organ placed between the bladder and rectum. Its texture is fibrous, but is much firmer than muscular substance. The broader portion or body of the uterus contains a triangular cavity, from each of two corners of which a tube, termed the Fallopian tube, leads towards the ovaries. The Fallopian tubes are about five inches in length: they become tortuous and enlarged towards their ovarian extremity, which is open, and fringed with irregular filaments or fimbriæ, that are capable of attaching themselves to the ovaries. The division of the Fallopian tubes extinguishes the sexual appetite.

The third or lower corner of the cavity of the uterus leads by a long channel, called the cervix uteri, into the cavity of the vagina. Its opening, which is a transverse slit half an inch in length between two fleshy lips, of which the posterior is the roundest and fullest, is called the os uteri.

The vagina is a mucous canal surrounded by a thick vascular membrane. At the orifice are the labia and clitoris; and in virgins a crescentic fold of membrane, termed the hymen, is found, leaving a narrow aperture.

The testes are glandular bodies, which form the organs essential to the genital system in the male sex. Either testis is suspended in the scrotum by a part called the spermatic cord, which consists of the spermatic artery and veins, of the spermatic plexuses of nerves and absorbents, and of the vas deferens, or excretory duct of the testis. The testis is covered with a serous membrane called the tunica vaginalis. When the reflected layer of this membrane is divided, the testis is found to consist of a flattened oval substance; to the upper outer and back part of which a narrow slip of tubular parenchyma adheres, called the epididymis.

The vas deferens becomes extremely tortuous as it approaches the testis. When this duct has been injected with quicksilver in the direction towards the body of the gland, we discover that the epididymis is but a continuation of the same canal now reduced to a much less diameter, of enormous length therefore, though coiled upon itself into so small a compass. The upper end of the epididymis again leads by six or seven convoluted tubes, called vasa efferentia, to the upper part of the testis, the texture of which is firmer and denser than the rest;

this part is termed the corpus Highmorianum, or rete testis. It consists of a network of tubes continuous on the one hand with the vasa efferentia, on the other with numerous isolated tortuous excretory tubes, the aggregation of which forms the testis. The connection between the veins and arteries of the testis and the excretory tubes has not been shown.

The vas deferens is of great strength and thickness. Upon dividing it near the testis in adult animals recently killed, a fluid is obtained, which consists chemically of water, mucus, soda, and phosphate of lime; and contains numerous minute animalculæ, which, as they are seen in the dog, have a head, a body, and a long filiform tail. These animalculæ are not found in the seminal fluid of mules *.

The division of the spermatic cord on both sides, or the removal of both the testes, destroys the sexual passion, and produces impotence.

The vas deferens reaches the lower opening of the pelvis by a circuitous route: having passed into the abdomen through the spermatic passage, it descends by the side of the bladder to the under part of its cervix, where it is joined by an oblong body called the vesicula seminalis: the latter part consists of a long blind tube, folded upon itself, the open extremity of which enters the vas deferens at an acute angle. The common duct after this junction is a third of an inch in length: it perforates the prostate gland between the inferior lobe and the lateral lobes, to open upon the under part of the urethra by an aperture at the side of the caput gallinaginis.

The prostate gland is of the size of a small chesnut, and of a very firm texture; its numerous ducts open in the furrow at the side of the caput gallinaginis, and pour out, when the gland is squeezed, an opaque whitish liquid.

The glands of Cowper seem likewise to belong to the generative system: commonly extremely minute, they are sometimes met with of the size of peas, one being placed on each side of the membranous portion of the urethra, below which they are united by an isthmus: the duct of each, about three inches in length, opens by perforating the mucous membrane lining the spongy body of the penis.

* Magendie, Elémens de Physiologie, vol. ii, p. 518.

The secretions of these parts find therefore a ready passage into the bulb of the urethra, from whence they are expelled by the action of the ejaculator seminis.

As in plants the organs of reproduction grow and are shed annually, in animals they are in vigour during a period only of their existence. The time at which their development takes place in man is termed puberty: before this arrives, the sexual organs of either sex do not participate in the growth of the body, but enlarge in a much slower ratio.

Antecedently to puberty, the physical character of the two sexes is the same: the same delicacy of complexion, and high pitch of the voice, and slightness of the figure, are met with in either sex. And many striking observations go to prove, that the changes in these points, which supervene with puberty, are in fact, as one would superficially conjecture, direct and immediate results of the development of the sexual organs mysteriously influencing the growth of the rest of the frame. The facts to which I advert are the following.

The removal of the testes, or the division of the spermatic cords in young male animals is followed occasionally by the animal attaining a larger size than it would otherwise have reached. But the shape of the mutilated animal has never the perfect character of a male; the neck and shoulders are commonly deficient in breadth and strength, while the loins are generally large and heavy.

In boys, castration prevents the enlargement of the larynx and the growth of the beard, and the whole frame when grown up presents an inconsistent and effeminate character; the skin soft, the body unusually fat.

Where parts of the genital system are naturally deficient, the body never acquires the true character of either sex. A marine aged twenty-three was admitted, in the year 1779, into the Royal Hospital at Plymouth: he had been there only a few days when a suspicion arose of the individual being a female. He had no beard: his breasts were fully as large as those of a woman at that age: he was inclined to be corpulent: his skin was uncommonly soft: the hands fat and short: the thighs and legs like those of a woman. The penis was found to be unusually small, the testes not larger than in the fœtal state.

Sir Everard Home, who describes the preceding case in the Philosophical Transactions, mentions likewise the following.

A female lived to the age of twenty-nine years, who was of a fair florid complexion, in stature not more than four feet six inches: her breadth across the chest was fourteen inches; across the pelvis but nine: her breasts and nipples had not enlarged. She had never menstruated. There was no appearance of hair on the pubes, nor was there any indication of puberty in body or mind at twenty-nine years of age. It was found, on examining the body after her death, that the os tincæ and uterus had their usual form, but had never increased beyond their size in the infant state. The passage into the uterus through the cervix was of the common shape, and the Fallopian tubes were pervious to the fimbriæ. The coats of the uterus were membranous. The ovaries were so indistinct as rather to show the rudiments, which ought to have formed them, than any part of the natural structure.

Mr. Hunter has described the nature of a peculiar monstrosity which occurs in black cattle, and which throws additional light upon the present subject.

When twin calves are born, they may be both perfect bull or perfect cow calves: when one is a bull calf, the other a cow calf, the latter in general when grown up exhibits no sexual propensities, and has a frame resembling the common ox, with which animal it is generally yoked and employed. This animal is termed a free-martin. Upon an examination of three of these animals, Mr. Hunter found in them different malformations of the genital organs: each of them had some rudiment of the female organs, but at the same time something deficient, either in the connection of the uterus with the vagina, or in the development of the ovaria; and in each some small part of the male generative system was detected. In this instance, therefore, as in the preceding, the general character of the animal seemed to follow the type of the genital organs.

The free-martin is perhaps the nearest approach in the higher animals to the state of hermaphrodism, the existence of which in human beings is a groundless fiction. Those appearances, which are occasionally exposed to the vulgar as specimens of such an occurrence, are cases in which, if females, there is an habitual prolapsus of the uterus with a long and narrow cervix, or an enlarged clitoris; or in which the front of the bladder and the lower part of the abdominal parietes are deficient, so that the everted mucous surface of the posterior half of the

bladder presents the appearance of a glans penis above the female sexual organs; — in males, the want of a perforation in the penis, with a deficient septum scroti, and the urethra opening in the perineum, have given rise to a similar mistake.

The period of puberty differs, in the two sexes, in the inhabitants of different climates, in persons of different temperaments and habits of life.

Women reach the period of puberty one or two years before men; the inhabitants of southern, before those of northern climates. In the hottest regions of Africa, Asia, and America, girls arrive at puberty at ten, even at nine years of age; in France not till thirteen, fourteen, or fifteen; whilst in Sweden, Russia, and Denmark, this period is not attained till from two to three years later. Habits of activity and bodily exertion retard the arrival of puberty.

At the time of puberty, in the male, the larynx enlarges, the quality of the voice is changed, the beard grows, the chest and shoulders enlarge, the generative organs are developed, hair grows upon the pubes, and the secretion of the seminal fluid begins.

The female at the age of puberty deviates less from the type of childhood; but the breasts enlarge, the pelvis enlarges, the uterine organs are developed, and a peculiar periodical secretion commences from the inner surface of the uterus, which continues, subject to certain intermissions, as long as the organ is capable of impregnation, which is on an average about thirty years.

This secretion is termed the menstrual discharge, or catamenia: it returns every lunar month, and consists of a fluid resembling arterial blood, except that it does not coagulate: the secretion amounts to six or eight ounces on an average, and lasts from three to four days. But in some instances the period returns regularly every third week; and in other instances, in which the common period is usually observed, it occasionally happens that menstruation is put off till the fifth week without any inconvenience attending: in some persons it lasts a shorter period than that above stated, and is scarcely sanguineous; in others it is more profuse, and lasts at each recurrence a week.

In some instances menstruation takes place at puberty, without any previous or attendant indisposition; but generally its

first appearance is preceded by uneasy feelings, by pain about the back and pelvis, accompanied often by disorder of the stomach and bowels, and various hysterical symptoms. These affections gradually abate, but at the end of a month return with more severity, being attended with colic pains, a frequent pulse, occasionally with heat of skin and a desire to vomit. There now takes place from the vagina a discharge of a serous fluid slightly red, but it does not in general become perfectly sanguineous for several periods: when the discharge flows, the preceding symptoms abate: but frequently a considerable degree of weakness remains, and the skin of the eyelids appears discoloured. In a short time menstruation is performed often without any other inconvenience than a slight pain in the back, though sometimes a woman may suffer from many of the former symptoms every time that she is unwell; and all women at the menstrual period are more liable than at other times to spasmodic and hysterical complaints.

This secretion is naturally wanting during utero-gestation, and some time subsequently. Yet there are instances, in which menstruation takes place exactly in the usual manner during the whole term of pregnancy. I have met with but one case of this description: the patient informed me that it had happened in each of seven pregnancies.

It is supposed that the uterus is peculiarly fitted for impregnation immediately after the period has ceased. Yet women may have children antecedently to the occurrence of menstruation. Sir E. Home mentions the case of a young woman, who was married before she was seventeen, and having never menstruated, became pregnant: four months after her delivery she became pregnant a second time; and four months after the second delivery, she was a third time pregnant, but miscarried. After this she menstruated for the first time, and continued to do so for several periods, and again became pregnant *.

Mr. Roberton gives, in the North of England Medical and Surgical Journal, the following table of the period at which 326 women in the Lying-in Hospital in Manchester began to menstruate.

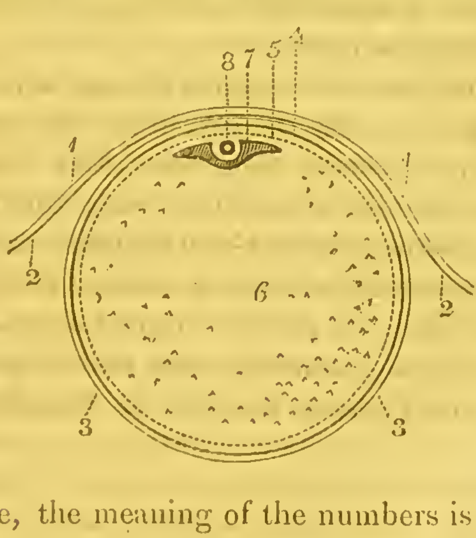
* Phil. Trans. vol. cvii, p. 258.

At 11 years	6
12	12
13	31
14	60
15	72
16	54
17	50
18	19
19	18
20	4

Like other peculiarities of constitution, the period of puberty in women is often found the same in members of the same family. Mr. Roberton mentions five sisters who menstruated at 11; one of them was gravid and a mother at 12.

We have now to inquire into the conditions necessary for impregnation.

For this purpose, germs are in a state of progressive forwardness in the ovaries, from the time of puberty till the period of child-bearing is over. These germs were seen for the first time by Baer, in the year 1827, in the ovaries of a bitch. They are little specks in the Graaffian vesicles, and in the bitch are from $\frac{1}{600}$ to $\frac{1}{250}$ of an inch in diameter, the larger being doubtless the more forward. The following diagram, taken from Baer, may serve to explain his notion of the structure of the Graaffian vesicle, and of the place and nature of the germ.



In this figure, the meaning of the numbers is as follows.

1. The peritoneal coat of the ovary.
2. The proper or cellular coat of the ovary.

3. The thin outermost coat of the Graaffian vesicle, framed of a close filamentous tissue.

4. The internal layer, thicker, softer, more opaque than the outer, from which it is after maceration readily separable. Its inner surface is slightly villous.

5. The granular membrane, immediately including the humour of the Graaffian vesicle.

6. The humour itself, slightly viscid, albuminous, pellucid, but inclining to yellow in the most turgid vesicles, containing numerous irregularly-shaped granules, with here and there a globule of oil.

7. The discus proligerus, or germ disc, composed of closely-coherent granules, which forms the bed in which is placed —

8. The germ or ovulum, itself a hollow membranous sphere, which consists of coherent granules.

There is every reason to believe, that Graaffian vesicles are at regular or irregular intervals coming forward during the whole period at which child-bearing is possible; and that they burst in succession, and shed the contained ovula, whether sexual connection takes place or not. It is probable, however, that sexual connection hastens their ripening. A principal difference in the appearance of the ovary of one past the age of thirty, and that of a child, is the scarred and cicatrized surface of the former contrasted with the uniform smoothness of the latter. The cicatrices on the former result, beyond question, from the healing of numerous lacerations of the surface produced by the escape of ovula.

The appearance termed a corpus luteum is the consequence of the bursting of a Graaffian vesicle. It is formed by a thickening of the internal coat of the latter. Baer mentions, that the thickening is sometimes found before the vesicle bursts*. The yellow colour (from which the term is taken) is in some degree accidental, or it is seen in some instances and not in others. The most perfect corpus luteum, which I have had an opportunity of examining, was found in the ovary of a young person dying about the end of the second month of pregnancy. It is in a specimen of Mr. Sweatman's, in the museum of the Middlesex Hospital, to which I shall afterwards have occasion more particularly to refer. The corpus luteum in

* De Ovi Mammalium et Hominis Genesi. C. E. a Baer. Lipsiæ, 1827.

this case is a flattened oval, $\frac{42}{30}$ of an inch in its long diameter, $\frac{1}{2}$ an inch in height. The cavity is irregular, its long diameter $\frac{18}{30}$ of an inch; its sides were almost in contact however. The opening through the peritoneal coat of the ovary still remains. The mass of the corpus luteum is made up of a spongy thickening of the inner coat, internally nodular, very much corresponding with Baer's figure. It is surrounded by a large plexus of veins and arteries, which likewise penetrate the spongy thickening mentioned. There is no yellow matter about it.

What the condition of the Graaffian vesicles may be, that renders them fit for impregnation, has not yet been determined.

It is not known whether a state of increased vascularity in the uterus and ovaries in women is necessary for impregnation. Some change of this kind is observed in the sexual parts of female animals, when they are in their periodical state of sexual excitement. Mr. Cruickshank thus describes the appearance of the parts in the rabbit.

A female rabbit, when hot, was pithed, and the uterine system was then minutely examined. The external and internal parts of generation were found black with an unusual quantity of blood: the Fallopian tubes were twisted like writhing worms, and exhibited a very vivid peristaltic motion: the fimbriæ embraced the ovaries, like fingers laying hold of an object, so closely and so firmly as to require some force and even slight laceration to disengage them: round black spots somewhat less than mustard seeds appeared below the membrane of the ovarium. Upon injecting the vessels of the pelvis with size and vermilion, the uterine organs became of a bright red.

When the uterine organs are disposed towards conception, what conditions are immediately requisite for the fecundation of ovula? Upon this subject our knowledge is extremely imperfect; but proceeding by the inductive method, physiologists have ascertained, that the exclusion of one element of the usual constitution of the uterine system essentially prevents impregnation following sexual connection. *If the canal leading from the orifice of the vagina to the ovaries is interrupted, conception never takes place.*

Dr. Blundell found, that an interruption of the uterine canal in rabbits, produced by the division of the vagina, uniformly prevents conception. Yet in animals thus mutilated, which admitted the male, the uterus afterwards enlarged to a con-

siderable size, and was found to contain a fluid of an albuminous nature *.

Barrenness in married women occasionally depends upon an obstruction of the os uteri by viscid mucus; the removal of the obstruction by a bougie has been shortly after followed by conception.

Dr. Haighton divided the Fallopian tubes on each side in several female rabbits, and found that the animals invariably lost the sexual appetite †. Upon dividing the Fallopian tube on one side only, he found the same result generally ensue. In a few cases, however, the animals thus mutilated admitted the male, and became impregnated: but the horn of the uterus on the side on which the Fallopian tube had been divided never contained ova.

When we refer to analogy for an explanation of the cause, why an obstruction of the uterine canal prevents conception, we discover it in the fact, that in various cold-blooded animals the seminal fluid is brought into actual contact with the eggs either at the time of their expulsion or afterwards. We are thus led to conjecture, that in warm-blooded animals likewise the seminal fluid must be directly applied to the germ, in order that impregnation may take place; and that any cause which prevents this contact taking place is enough to prevent conception.

If we are satisfied that this conjecture is well founded, we may next inquire, whether the contact of the seminal fluid and ovum takes place in the uterus, in the Fallopian tube, or in the ovary. The only facts of which we are in posssesion, that seem to bear upon this question, are, that the ovum, although in most cases developed in the uterus, yet is sometimes brought to maturity in the Fallopian tube, sometimes in the peritoneal cavity, and sometimes even in the ovary: it is remarkable that in the three latter cases the uterus enlarges, and its inner surface becomes covered with a layer of flocculent lymph, much in the same manner as in cases of ordinary conception. Yet curious as these facts undoubtedly are, they leave the point which I have adduced them to elucidate nearly in its original uncertainty.

* Medico-Chirurgical Trans. vol. x, p. 50.

† Phil. Trans. vol. lxxxv, p. 108.

My colleague, Mr. Sweatman, has the following remarkable preparation. It is the uterus of a hare, with two embryos, which are situated one in each of the horns of the uterus. Now these horns are cavities that open separately into the vagina, and have no direct communication. There are likewise in this specimen two corpora lutea; but these are contained in the same ovary. How did the second reach the further horn? The two corpora lutea are of the same size and appearance, and there is no corpus luteum in the other ovary.

It has been mentioned, that Graaffian vesicles are for a period continually coming forward in the ovaries. What determines their fitness for fertilization is not known. But as on the one hand it may frequently happen, that sexual intercourse produces no conception in mature ova; so on the other does it appear certain, that sexual intercourse will sometimes not only produce in a mature ovum conception, but strongly influence and give a character to the immature ovula, for the fecundation of which a subsequent coïtus may be necessary.

The remarkable instance which brought this fact into notice is the following:—A seven-eighths Arabian mare belonging to the Earl of Morton, which had never been bred from before, had a mule by a quagga: subsequently she had three foals by a black Arabian horse. The two first of the foals are thus described. "They have the character of the Arabian breed as decidedly as can be expected, where fifteen-sixteenths of the blood are Arabian; and they are fine specimens of that breed; but both in their colour, and in the hair of their manes, they have a striking resemblance to the quagga. Their colour is bay, *marked more or less like the quagga* in a darker tint. Both are distinguished by the dark line along the ridge of the back, the dark stripes across the fore-hand, and the dark bars across the back part of the legs. Both their manes are black; that of the filly is short, stiff, and stands upright: that of the colt is long, but so stiff as to arch upwards, and to hang clear of the sides of the neck; in which circumstance it resembles that of the hybrid. This is the more remarkable, as the manes of the Arabian breed hang lank, and closer to the neck than those of most others *."

A similar occurrence to the preceding is mentioned by

* Phil. Trans. 1821, p. 21.

Mr. Giles respecting a litter of pigs, which resembled in colour a former litter by a wild boar.

Women, it is said, have borne twins by different fathers. This occurrence involves, it is evident, no physical improbability. It is even physically not impossible, that in those cases, in which menstruation continues during pregnancy, a second impregnation may take place at some interval after the first but antecedent to the expulsion of the first embryo.

We may suppose the reason of the occasional production of twins, or of more, at a birth, to be the accident of several ova having ripened, and been fertilized simultaneously. Baer mentions having twice seen, in the ovaries of animals, two ovula in one Graaffian vesicle: but this occurrence probably gives rise, not to the birth of ordinary twins, but to the varieties of *united* births.

SECTION II.

Of the Development of the Embryo.

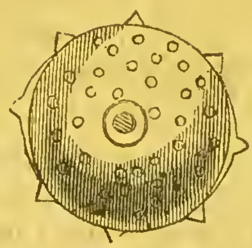
The detection, by Baer, of the ovulum in mammalia, which has been mentioned in the preceding section, is a point only in the extensive circle of discovery which has been traced by himself and by other physiologists. According to ancient hypothesis, the development of the embryo was the evolution of parts which pre-existed in the germ. This opinion was first successfully attacked by C. F. Wolff, in a thesis which he published at Berlin in 1759, and in which he not only described a successive production of organs, of the pre-formation of which no trace existed; but showed, that, after parts are first formed, they undergo many important changes in their structure before arriving at their perfect state. The opinions of Wolff, that the parts of the embryo are formed and not evolved, have been verified, and a vast body of knowledge ascertained upon this subject, by the labours of Pander, Meckel, Oken, Blumenbach, Baer, Rathke, Cuvier, Dutrochet, Serres, Rolando, Prevost, Dumas, and of many others, who have joined in creating a new branch of physiological science. I shall endeavour briefly to explain the leading facts which have been thus brought to light. They have an interest greatly beyond twha attaches to

the narration of phenomena that are simply unexpected and curious. They elucidate to a wonderful degree the affinities of remote families of animals; displaying how for a period their type of formation is the same, and explain the seeming caprice of Nature in instances of monstrous and defective formation, by showing that what appears anomalous is not the substitution of a new type, but the arrest of development, whereby a temporary character is rendered permanent.

The ovulum bursting from the Graaffian vesicle is received by the fimbriated extremity of the Fallopian tube, and conveyed towards the uterus.

Baer detected the ovulum in its passage along the Fallopian tube in a bitch. Its appearance is represented in the adjoined figure. It was of a yellowish-white colour, and consisted distinctly of an outer cortical membrane, or chorion, and of a globule within of a granular structure. Its diameter was the fifteenth part of a line.

After reaching the uterus, the ovulum grows more rapidly than before. Its structure may be examined with ease, when it is about half a line in diameter. A new element is then visible in it, which is shown in the adjoined figure from Baer. Upon the surface of the internal globule, a round, opaque, granular disc is seen, with a dark spot upon its centre. Dr. Allan Thompson, from whose useful papers on embryology, in the Edinburgh New Philosophical Journal, I have borrowed the greater part of the preliminary sketch in the present section, states, that he has seen this spot very evident in the ova of the rabbit on the sixth day after impregnation.



It does not, I think, admit of a doubt, that the spot seen on or through the inner membrane of the ovum corresponds exactly with the *cicatricula of the egg*. This conclusion is grounded, less upon their first close resemblance than on the

subsequent identity of the parts which replace them; less upon either argument than upon both together. The intermediate state to the two which I refer to, has not been as yet followed out in mammalia. I therefore shall describe the cicatricula in the egg, and its first changes, as typifying what analogy renders certain occurs in all vertebral animals.

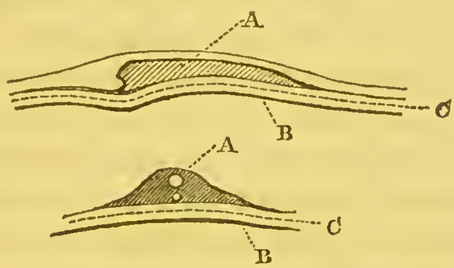
In the unincubated egg of the common fowl, the germ spot, or cicatricula, lies immediately upon the surface of the yolk: it is circular, of a whitish colour, and about one-sixth of an inch in diameter. The disc of the cicatricula is formed of different-sized granules united together, and is covered by the proper membrane of the yolk. The central part of the disc is thinner and more transparent than the rest, and has been called the colliquamentum.

Seven or eight hours after the commencement of incubation, a small dark line may, with the aid of a magnifying glass, be discovered on the upper part of the cicatricula towards the centre of the transparent area. This line, or *primitive trace*, delineated in the adjoined figure, is swollen at one extremity, and is placed in the direction of the transverse axis of the egg. The rounded end is towards the left, when the small end of the egg is turned from us.

The cicatricula, germ spot, germinal membrane, or blastoderma, resting in immediate contact with the yolk, now expands itself; and at the same time acquiring thickness, it separates, towards the 12th or 14th hour of incubation, into two layers of granules. Of these, the outer, which subsequently gives rise to the osseous, nervous, muscular, and tegumentary systems of

the body, is called by Pander the serous layer. The inner, situated next to and in contact with the substance of the yolk, is termed the mucous. After these two layers have appeared, a third is formed in the interval between them: this is called the vascular layer; it is generally in intimate connection with the mucous layer, and it is to the changes which the two combined undergo, that the intestinal, the respiratory, and the glandular systems appear to owe their origin.

The primitive trace is placed in the outer or serous layer. About the 18th hour, two ridges are raised from the serous layer, one on either side of the primitive trace [the *plicæ primitivæ* of Pander, the *laminæ dorsales* of Baer]. About the 20th hour, the furrow between the ridges is converted into a canal open at both ends, by the junction of its margins. The canal soon becomes closed at the cephalic or swollen extremity of the primitive trace, at which part it is of a pyriform shape, being wider here than elsewhere. The following figures represent a longitudinal and a transverse section of the triple layers of the germinal membrane at this period.



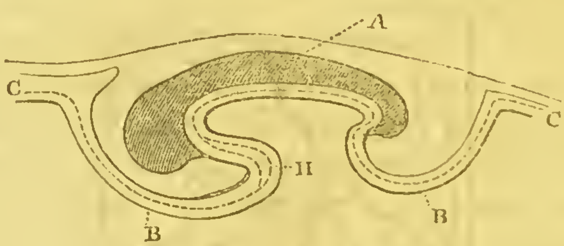
A represents the serous layer, B the mucous, the intermediate dotted line C the vascular.

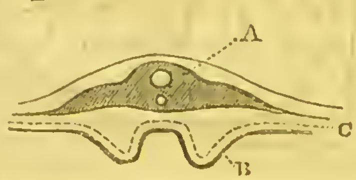
According to Baer and Serres, some time after the canal begins to close, a semi-fluid matter is deposited in it, which, on its acquiring greater consistence, becomes the rudiment of the spinal cord. The pyriform extremity, or head, is soon after this seen to be partially occupied by three vesicles, which, being also filled with a semi-fluid matter, give rise to the rudimentary state of the enkephalon. Rolando, Prevost, and Dumas, on the other hand, suppose that the rudimentary state of the brain and spinal cord is constituted by the primitive trace itself, which they affirm exists before incubation has commenced.

As the formation of the spinal canal proceeds, the parts of

the serous layer which surround it, especially towards the head, become thicker and more solid; and before the 24th hour, we observe on each side of this canal four or five small, round, opaque bodies. These bodies indicate the first formation of the dorsal vertebræ: in a few hours several more appear, and those first produced become quadrilateral. It is about this time, or from the 20th to the 24th hour, that the vascular layer appears.

Towards the 25th hour, when the layers of the germinal membrane gradually expanding have covered nearly a third of the yolk, they no longer retain their flat and uniform position, but begin to exhibit various folds, which afterwards serve for the formation of the cavities of the body. That part of the germinal membrane which lies immediately before the cephalic extremity of the embryo is bent down into a fold, so as to make a depression upon the surface of the yolk; and some time afterwards, a similar fold is formed behind the caudal extremity. As these folds of the germinal membrane increase, they gradually turn in below the fœtus at its head and tail; and their margins approach one another under the abdomen, which at this period always lies next to the substance of the yolk. As the layers of the germinal membrane are bent down in a similar manner towards the sides also of the spinal canal, there is formed under each end of the embryo a sac or cavity, which communicates with the yolk by an opening common to both. The two shut sacs thus formed indicate the rudimentary state of the intestinal tube: the anterior corresponds to the œsophageal portion of the intestine, the posterior to the lower part of the large intestine.



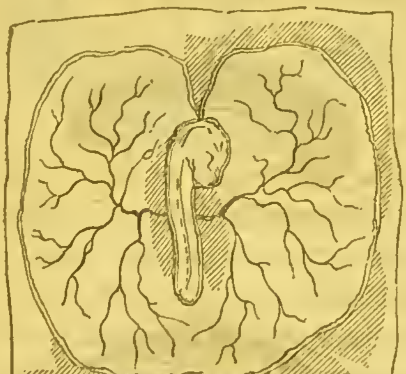


In the two preceding figures are given sections, corresponding to the last, of this progressive increase.

The first rudiments of the heart appear towards the 27th hour on the lower side of the œsophageal canal, at the place where the layers of the germinal membrane are reflected from the edge of the anterior or cephalic end of the embryo. In the fold which is formed at this part, the mucous layer [B] is reflected farthest inwards; the serous layer advances least; the space between them, occupied by the vascular layer, is filled up by a dilated part of this layer [H], which is the rudiment of the heart.

About the same time that the development of these rudimentary parts of the embryo takes place, the surrounding disc of the cicatricula is also considerably changed. The whole cicatricula continues to expand, and to cover more of the surface of the yolk. That part of the mucous and vascular layers which surrounds the transparent area, becomes thicker and more spongy than the adjacent parts, and is soon studded with numerous irregular points and marks of a dark-yellow colour. As incubation proceeds, these points become more apparent, and are gradually elongated into small lines which are united together, first in small groups, and then into one network, which is called the vascular area.

The space occupied by this network is cordiform, and is surrounded by a vessel gradually developed in the same manner as those of the rest of the area. The newly-formed vessels of the space become more and more distinct as incubation advances, and the orange-coloured fluid they contain acquires a darker hue: the small branches of the network arrange themselves like the fibrils of a leaf on each side of the embryo, and terminate



towards the embryo in two vessels arising from its sides, which are the omphalo-meseraic arteries. Towards the circumference

of the area, the smaller ramifications of these vessels open into the sinus, or vena terminalis, which bounds the space.

Changes parallel to these described in the egg have not been observed with equal success in the germinal membrane of mammalia; the grounds upon which we may presume that they take place are the following.

The original parts of the ovum in mammalia appear to be the same as those in the egg. The egg consists of two membranes, the membrane of the shell and the membrane of the yolk, the cicatricula within the innermost. The ovum of mammalia, when half a line in diameter, consists of two spherical membranes and a germ spot.

In the egg, the primitive trace is seen in the cicatricula seven hours after incubation has begun. Its figure has been already given. In the ovum of mammalia, Baer and Prevost and Dumas concur in stating, that the first trace of the embryo appears like a dark line near the middle of the central transparent part, which is exactly as the primitive trace shows itself in the transparent area of birds.

Finally, the disposition of parts in the incubated egg at the period to which we have already traced its progress, is closely paralleled in the ovum of mammalia at a very early period. The adjoined figure, taken from Baer, represents appearances strictly comparable to those in the last diagram.

It represents the ovum of a bitch at the third week; in which are shown, first, the outer flocculent tunic, or chorion; next, the yolk bag, or vesicula umbilicalis; and in connection with it, the embryo, by this time as in the egg inclined upon its left side, with vessels spreading from it to form a vascular area.

The doubt, if there is room for doubting the correctness of the parallel thus instituted, refers to points now passed. Beyond these, the closest parity of development obtains throughout ver-

tebral animals, arrested only at particular limits to suit the prescribed organization of each race.

In unfolding the complicated subject which now opens upon our view, I shall adopt the following method. I shall begin by describing in succession, the formation of the parts of the embryo; 1. Of the brain, nerves, muscles, and organs of the senses, of the bones and cartilages, and of the integuments—the produce of the serous layer; 2. Of the alimentary canal and glands,—the produce of the mucous layer; 3. Of the heart and blood-vessels, which grow out of the vascular layer.

The consideration of the development of the vascular layer will on the one hand complete the account of the embryo, and on the other lead by a natural transition to the history of the production of the remaining parts of the ovum; in explaining which, I shall finally transform the ovum from the structural character which up to this point will have been attributed to it—that namely of a double sac, representing the membranes of the egg with the germ laid upon the contained yolk—into the more familiar structure of chorion and placenta and umbilical cord, and fœtus suspended by the latter, and floating in the water of the amnios.

I. The formation of the spinal cord and brain begins upon the outer surface of the serous layer. When first seen these parts are together a line and a half in length; the cephalic extremity is a rounded nodule. Both parts appear at once. The brain does not grow from the spinal marrow, nor the spinal marrow from the nodule which represents the future brain.

The spinal cord is at first a membranous tube, the brain three vesicles. In these a transparent fluid is contained, from which a precipitation takes place of opaque particles connected by a viscid transparent substance. The precipitated matter at first adheres closely to the membrane; then gradually loosens itself from it. The nervous substance is formed out of the primitive or elementary matter of the embryo antecedently to the production of those vessels, through which its increase is doubtless effected.

Nervous matter, at first of the consistence of a thick fluid, by the third month is evidently composed of two substances: one consisting of medullary threads, which by maceration in alcohol are displayed in the embryo even more easily than in the adult; the other, not fibrous, or filamentous, or fascicu-

lated, being that which at a later period assumes a grey or cineritious colour.

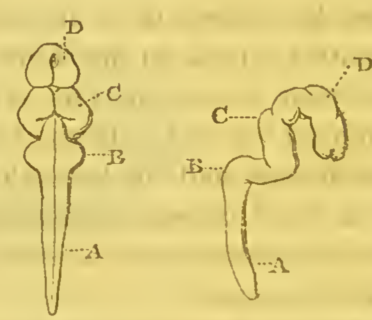
The spinal cord and brain are not originally composed of symmetrical halves. This character results from the development of additional matter upon their sides.

The anterior part of the spinal marrow grows more rapidly than the posterior part. The development of the sides produces a groove open backward. This groove or furrow is visible at the sixth week. The gradual increase of the sides spreading inwards and finally meeting closes this furrow superficially, and converts it by the sixth month into a canal. Afterwards the canal itself, by an extension of the same process, becomes obliterated. The upper part of the canal is the last to close.

The spinal cord in an embryo of three months is as long as the vertebral column. Soon after this period, the growth of the vertebral column gains upon that of the cord; so that at the seventh month the cord extends as low only as the fifth lumbar vertebra, at the ninth to the second only.

The enkephalon consists originally in all animals of three sacs, which are the rudiments of the medulla oblongata, of the tubercles, and of the cerebrum: these are filled with transparent fluid, and have no disunion in the median plane. Such is the appearance of the enkephalon in fish at the earliest period, in the embryo of the chick on the second day, in the human embryo during the fifth week.

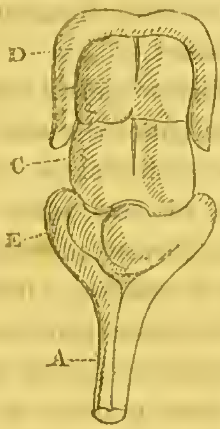
The two adjoined figures, from Tiedemann, represent a back view and a side view of the spinal cord and brain in an embryo of six weeks.

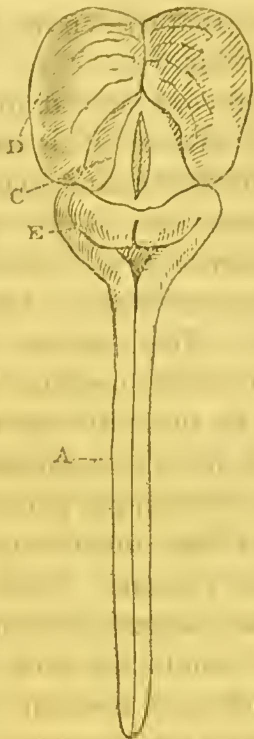


A. Represents the spinal cord.
B. The medulla oblongata.
C. The tubercles.
D. The cerebrum.

The two figures which follow successively represent the brain as seen from behind and above, at the ninth and twelfth weeks. The letters are the same as to the preceding.

The letter E added in these figures represents the cerebellum.





The enkephalon of the embryo, is proportionately larger than that of the adult. At the fifth month it forms one-eighth, soon after birth one-tenth of the entire weight, of which in adults it forms one fortieth only.

The medulla oblongata is more developed than the rest of the enkephalon. According to Tiedemann the breadth of the medulla oblongata is to that of the cerebrum in the second month 1 : 1.25, in the third 1 : 2 or 3, in the fourth 1 : 3.2, in the fifth 1 : 4.8, in the sixth 1 : 5, in the tenth 1 : 5.63, in adults 1 : 6 to 7. In the tenth month the medulla oblongata has already half the breadth which it attains in the adult.

In the fifth week, according to Tiedemann, the decussation of the pyramids may be seen: about the same time the corpora olivaria appear.

The cerebellum is not an elementary part of the enkephalon. It is produced by an extension of the lateral parts of the medulla oblongata or of the corpora restiformia, in the egg of the common fowl on the fourth day, and in the human embryo about the seventh week. The cerebellum at its commencement consists of two processes, which meet but do not join as yet over the medulla oblongata. These two lateral processes in the human embryo coalesce about the beginning of the third month,

and enclose a space [the future fourth ventricle] between the cross band which they form and the medulla. The corpora fimbriata appear in the fourth month in the form of shut sacs or bladders: they are rich in blood-vessels. As they increase, now in the fifth month, the hemispheres of the cerebellum begin to be developed, and at first towards the fore part principally. Additional layers of nervous matter are now produced, and the mass divides itself into the rudiments of five lobes. The transverse furrows which separate the lobes are first visible upon the middle part or the future vermiform processes. In the sixth month more furrows are traced upon the surface, and the lobes divide themselves into lobules. In the seventh month the furrows become deeper and more numerous: the flocks and the inferior medullary velum appear at this time. In the ninth month the development of the hemispheres is nearly completed by the additional growth of the posterior and inferior surfaces. In the tenth month the superficial furrows, and the laminæ which they include, appear. The almond-like lobes are finally developed, and the distinction between white and grey matter is seen.

The pons Varolii appears at the beginning of the fourth month. The first part developed is the posterior portion; so that at first the fifth nerve has its origin *before* the pons.

The cerebellum does not keep pace in proportional volume in fœtal life with the other parts of the enkephalon; and if its inward structure is earlier perfected, this must be attributed to its simplicity.

The tubercles, original elements of the central organ, form at first a single bladder filled with transparent fluid. By the sixth to the ninth week this appearance has changed into two lateral plates resting upon the crura cerebri, and divided above and in the middle by a broad furrow. At the end of the third month the two lateral plates having bent over, meet in the median plane, and at the same time the upper pedicles of the cerebellum stretch forward to be incorporated with them. In the fourth month the permanent median furrow shows itself. In the sixth month the tubercles are covered with the cerebrum: their substance enlarges, and is clad with a layer that is not fasciculated, but as yet is of a grey colour. In the seventh month the transverse furrow which divides the tubercles into an upper and lower pair arises. The tubercles, in comparison

with the brain, are the larger the younger the embryo. Before birth, they attain more than half their final size.

The white inferior fasciculi of the crura cerebri grow consentaneously with the inferior or anterior fasciculi of the cord, of which they are the cerebral productions. They are at first large in proportion to the cerebrum. The cylindrical layer, which is placed upon them, begins to appear about the fourth month. This at first consists of two lateral parts, the furrow between which leads along the infundibulum to the pituitary gland. The pituitary gland contains a cavity which remains open to the sixth month. This cavity may be regarded as the anterior termination of the canal, which from thence extends backwards the whole length of the spinal marrow. The pituitary gland at four months is in length, compared with the brain, as 1 : 9.5; at seven, as 1 : 16; in the adult, as 1 : 18; showing therefore in the early human embryo a development like that which it permanently retains in the lowest vertebral animals.

The thalami nervorum opticorum and the corpora striata show themselves at the eighth week, as swellings upon the crura cerebri. The thalami are of a reddish hue. The posterior commissure is formed in the third month; the soft commissure in the fourth. The corpora striata, originally narrower and not much longer than the thalami, soon outgrow them.

In the third month either hemisphere consists of a thin layer, which covers the outer and fore part of the corpus striatum. By the end of the third month the hemispheres extend backwards over the thalami. In the fourth month they reach the tubercles; in the sixth, the fore part of the cerebellum. The fasciculated structure of the brain is even more distinct in the fœtus than in the adult.

The commissural parts of the brain begin to appear in the third month. It is far from improbable that the conjecture of the Wenzels is right, that the corpus callosum is formed by the union of two processes of medullary matter meeting at the raphe. The fore part of the corpus callosum is the first to appear. The fore part of the fornix appears at the same time, its anterior cornua stretching downwards, and terminating in the thalamus. The anterior commissure appears in the third month.

The convolutions of the brain are seen first at the fifth month: they are at that time formed upon the inner surface

and upon part of the upper surface of the cerebrum. In the seventh month they spread over its outer surface.

Of the ventricles of the brain, the first appearance of the third, and its closure above by the formation of the soft commissure, may be considered to have been already described. The lateral ventricles, which when first formed are open inwards and upwards, begin to be closed above at the end of the third month by the corpus callosum, the completion of which towards the eighth month shuts them in this direction. The formation of the septum lucidum begins in the fifth month. The relative size of the lateral ventricles is greatest at the sixth month. The central organ is originally of one colour, a pearly grey. The distinction between white and grey substance is first visible in the spinal marrow; in which, at the seventh month, the coloured nucleus presents a deeper shade even than after birth. The pyramids and olivary bodies become white after birth, as well as the exterior fibres of the annular protuberance and of the pedicles of the cerebrum. But the productions of these parts into the cerebrum and cerebellum become white before birth, leaving however the superficial cineritious matter of disproportionate thickness. The medullary line which divides the cortical matter into two layers appears after birth.

It is a question yet unresolved, whether the nerves in general are formed in their entire length at once, or, if not so formed, are growths from the central organ towards the circumference, or the reverse. But it is certain, that the optic, and auditory, and olfactory nerves are productions of the cerebrum. They are originally tubes that grow from the sacs of the enkephalon.

In the instance of the optic nerves, the tractus optici are seen first to grow from the enkephalon, then to meet and form their commissure, and finally to push out the nerves. It is therefore presumable upon analogy, that the other nerves are likewise from the first in absolute continuity with the cord, although the extreme delicacy of their roots may elude observation. The extraordinary circumstance observed by Magendie in the lamprey, is the only fact which throws a doubt upon this conclusion. In the lamprey, while the cerebral nerves distinctly rise from the enkephalon, the spinal nerves cannot be traced further than to the theca. I have carefully examined this point in the lamprey the instant after it has been killed,

and am certain that no visible continuity of filament extends in it between the membranes of the cord and the cord itself [vide foot-note to page 248].

The muscles become visible in the human embryo at the third month: they are then soft and gelatinous, transparent, of a light-yellow tint, and not distinguishable from their tendons. Their fibrous structure is evident after maceration in alcohol. In the fourth and fifth months the muscular fibres become more distinct, and of a redder colour: the tendons, on the other hand, become whiter. The muscles appear in different parts at different periods. They are first formed on the back and shoulders. Those of the upper arm and of the thigh are formed before those of the fore arm and of the leg. Each muscle is formed at once in its whole length, with its attachments perfect.

There is a close relation between the development of the muscles and of the nerves. In defective births, where the brain, spinal marrow, and nerves are wanting, the muscles likewise are wanting, and in their place a gelatinous filamentous tissue is found. In acephalous fœtuses, where part only of the central organ is formed, muscles are formed in particular parts only.

Of the organs of the senses, the eye is the first to appear. The human embryo has not been seen without eyes. Their growth is rapid. At first, as in most animals so in human beings, their place is on the side of the head: they subsequently move forward. The eyes, according to Baer's observations, are productions of the brain; their first element being a hemispherical mass on the end of the optic nerve, which is the retina. The retina is at first of great thickness, and folded: its subsequent increase is therefore less than that of other parts. It enlarges its surface by becoming thinner, and spreading its folds. At the sixth month the permanent fold of the retina corresponding with the visual axis is distinguishable.

The humours of the eye do not grow from the retina; for they have been found where the retina was wanting. At the seventh month the vitreous humour is turbid; it gradually becomes transparent. The lens is globular, originally very large, soft, untransparent, milk white; it then becomes reddish, and gradually smaller, flatter, more consistent, and more transparent. The cornea is originally indistinguishable from

the sclerotic: both have an equal degree of opacity. At the sixth month the cornea becomes thinner, denser, prominent, and transparent. The eyelids are formed by the tenth week, when their edges touch and adhere. The line of their separation is distinctly marked at the fifth month, when the tarsal cartilages are formed: their separation is complete in the eighth month. The third eyelid is larger than in adults. The caruncle is seen at the eighth week, when the eyelids are beginning to be formed; and at the same time a depression is seen towards the nasal cavities and mouth, marking the place of the future lachrymal duct. The puncta are prominent in the fifth month. They are something drawn back in the seventh.

The chorioïd must be viewed as a production of the vascular layer of the embryo. The pigment which it forms is visible in human beings as early as the fourth week. It is then granular and coherent, so as to appear a second membrane. It does not acquire in the fœtus the blackness it has after birth. The ciliary body is formed at a later period, as it has been already observed. The iris appears yet later; it is at first narrow, and not coloured: it gradually acquires breadth, forms the pupil, and begins to be coloured from its inner margin. At the seventh week the aperture of the iris is closed, and the anterior chamber of the aqueous humour has no outlet. This chamber now becomes universally lined with a serous membrane, the fore part of which adheres to the cornea, the back part to the iris. The membrana pupillaris is a production of the posterior surface of the iris. It is distinguishable by the eleventh week. In the fifth month it becomes replete with vessels produced from those of the iris. These do not completely reach the middle of the membrane. The membrane is perfected at the seventh month. In the eighth it becomes partially absorbed, and disappears completely before birth. Till its absorption, the lens rests against it. The aqueous humour secreted by the membrane of the anterior chamber then gains admission into the posterior chamber. During the fœtal state, the aqueous humour is reddish, and not quite transparent.

The organ of hearing, according to Baer, appears soon after the first appearance of the eye. What is first seen is the production of a hollow nerve from the medulla oblongata, which stretches into the soft cranial wall. Upon this the vestibule is

formed. By the beginning of the third month the cochlea and semicircular canals are added. These parts are covered with a membrane, which disappears in the seventh month. Around the labyrinth jelly is first deposited; cartilage begins to form in the third month, which is distinct from that of the petrous portion of the temporal bone, and develops ossific points earlier than the latter. It is completely ossified in the seventh or eighth month, and then becomes united with the petrous portion. The commencement of ossification appears at the same time in the three parts of the labyrinth; namely, at the end of the third month. The ossification of the cochlea begins at the circumference of the fenestra rotunda. The spiral plate is the part last formed. The ossification of the vestibule commences at the circumference of the fenestra ovalis: it is completed in the fifth month. Of the semicircular canals the upper vertical is the first ossified, then the lower, then the horizontal, the turn of which is delayed till the fifth month. The tympanum is at first proportionally small, and filled with reddish, thick, gelatinous liquid. In the eighth month it has acquired its full size. The Eustachian tube appears at first as a wide opening from the throat; its cartilaginous part appears in the fifth month. The ossicula auditûs appear in the ninth week, and are cartilaginous at the beginning of the third month. Shortly afterwards ossification begins in the incus and malleus; later in the stapes: it is completed in the seventh month. The stapes ossifies first in its base, last in its capitellum. The malleus, like the incus, ossifies first in its head; a second point of ossification afterwards forms in the root of its anterior process, of which the long and pointed cartilaginous end is then absorbed. The ossicula auditûs are before birth as large as in the adult.

The ring of the tympanum appears in the second month: it begins to ossify at the end of the third. It is incomplete at its upper and fore part. It continues to increase till the seventh or eighth month, becomes more elliptical, and ends by coalescing at its two points with the root of the zygomatic process of the temporal bone. The membrana tympani is more oblique in the embryo than in adults.

The outward aperture of the ear shows itself as a fine point or slit in the sixth week, which gradually extends inwards, and reaches the membrana tympani. At the eleventh week it

closes however temporarily by means of a membranous plug. The outer ear commences in the eighth week as a flat fold of integument, in which the cartilage begins to form towards the end of the third month. At first the middle parts of the helix and antitragus are formed, then the tragus and antihelix; in the fifth month the concha; in the sixth the upper part of the helix, and the lobe of the ear. The ear then detaches itself more from the head. At birth the cartilage does not adequately fill the skin.

The organ of smell, at first a cylindrical production of the cerebrum, is produced towards the anterior extremity of the mucous layer, where it forms the common cavity of nose and fauces. In the third month this cavity is divided into two by the formation of the palate, and the nostrils are further separated by a septum, in which the vomer becomes ossified in the fourth month. The nose appears in the eighth week. Its openings are closed by a production of integument, which disappears again in the fifth month.

The substance of the bones is at first an homogeneous jelly, which forms itself out of the granular material of which the embryo consists. The spinal column is at first such a jelly inclosed in a membrane, with no distinction of separate vertebræ. The bones of the limbs are in like manner preceded by a jointless gelatinous substance. The jelly gradually becomes cartilaginous, the conversion taking place from the surface inwards. Cartilage is first seen in the human embryo in the fifth week, when it appears in the bodies of the vertebræ, and in the ribs and sternum. The first rude subdivision of parts of the future skeleton now takes place. One hollow cartilage forms the head; another the pelvis. Each cartilage has its covering of fibrous membrane upon which blood-vessels are formed, which enter into and ramify on its substance. The presence of red blood is a condition necessary to ossification. In this process the cartilage disappears, and is replaced by threads of inflexible matter, which form a network or cellular structure. This change looks like a crystallization of bone earth in the interior of the cartilage. Two facts particularly deserve attention in it: one is, that the ossified plate or nucleus is easily separable from the cartilage which contains it; the other is, that when the bone earth has been removed by chemi-

cal re-agents, the animal structure which remains differs from cartilage.

Ossification begins in the human embryo in the seventh week.

In the following instances ossification takes place from a single point; — in the parietal bones, palate bones, malar bones, nasal bones, lachrymal bones, turbinated bones, clavicles, patellæ, in the bones of the carpus and tarsus with the exception of the os calcis.

Ossification takes place from two points, in the frontal bone, the vomer, the under jaw. In these instances the two points of ossification are on either side of the median plane. In other instances of a double centre of ossification, one ossified point is behind or above the other: this happens in the os calcis, the tarsal and carpal bones, and the phalanges.

Ossification takes place from three points, forming a middle and two sides, in the vertebræ and in the ethmoïd bone: from three points, forming a shaft and two epiphyses at the same end, in the ribs; or with an epiphysis at each end, in the radius, tibia, fibula. Ossification again takes place from three points in the upper jaw.

Ossification takes place from five points in the scapula, ulna, femur, os innominatum, and in the second and seventh cervical vertebræ; omitting in the last two instances, as in the foregoing account of the other vertebræ, the epiphytic rims and points of bones, which ossify independently some years after birth.

Ossification takes place from seven points in the humerus, from eleven in the occipital bone, from fourteen in the sphenoïd, from twenty-one in the sacrum, and from an irregular number in the sternum. The nuclei gradually extend, and when they meet coalesce; by which means during fœtal life the eleven elements of the occipital bone are reduced to seven, the fourteen of the sphenoïd to three.

In the human embryo the first ossific point appears in the clavicle towards the end of the second month; the next in the lower jaw, the next in the upper jaw, the next in the femur. During the first half of the third month ossification begins in the frontal and occipital bones, in the upper arm and fore arm, leg, scapula, and ribs. During the second half of the third month, in the temporal, sphenoïd, malar, parietal, nasal bones;

in the vertebræ, carpus, tarsus, and in the third phalanges. During the fourth month in the vomer, in the first and second phalanges, and in the ilium. During the fifth month in the ethmoïd, and lachrymal, and turbinated bones. In the seventh month in the os hyoïdes and ossa coccygis. The order in which the bones are ossified is not that in which their cartilages are formed: it has relation to the development of the vascular system. Thus at remote points parallel ossifications take place at the same time: and it deserves to be remarked, that in general the lateral ossifications take place the first; as if the force of vascular production were greater in the sides than towards the centre of the system, which it thus seems slowest in reaching. The best illustrations of this principle are met with in the ossification of the true vertebræ, of which the arches are the first to become bone; and in that of the ethmoïd, in which the lateral parts are first ossified; and in those instances among the symmetrical bones, in which ossification begins in pairs of nuclei on either side the median plane.

The bones of the embryo are flexible and of a reddish-grey colour, from their greater quantity of animal substance and greater vascularity. The periosteum is thicker, more vascular, and more easily separable than in the adult.

The epiphyses, or marginal and terminal cartilages which ossify separately, are continually encroached upon [and absorbed] through the extension of the body or shaft of the bone, towards which they present a concave surface, into which processes of this central part of the bone grow.

In the long bones the medullary cavity is early visible, closed only towards the ends by cancellated structure, in the cells of which a reddish gelatinous marrow is formed. In the flat bones there is neither marrow nor diploe during fœtal life.

Before birth ossification has not begun in the upper cornua of the os hyoïdes, in the patella, in the lower ossa coccygis, in the four upper carpal bones, and in the trapezium and trapezoïdes, in the naviculare and cuneiform bones of the tarsus.

In parts of other bones the following ossific nuclei are wanting: the vertical plate of the ethmoïd; the processes of the scapula; the upper epiphysis of the humerus, of the femur, and of the digital phalanges: in the tibia, as in the tarsal and metatarsal bones, the lower epiphyses: in the ribs the capitellum:

in the ulna, radius, and fibula, both epiphyses: in the atlas, the body.

The vertebral column, according to Beclard, begins to ossify at its middle: by the tenth week the bodies of twelve vertebræ, from the fifth dorsal namely to the fourth lumbar, contain points of ossification: in the eleventh, seven are added above, one below: in the fourth month two more above, the third and fourth cervical, and below, the four uppermost sacral; in the sixth month the fifth sacral; in the seventh the second cervical; in the ninth the atlas and the first coccygeal bone.

The vertebral column is at first straight. By the end of the second month the sacrum begins to be thrown backward. Till the third month the sacrum projects forming the coccygeal protuberance, analogous to the tail of fishes; it then shrinks within the growing pelvic extremities.

The embryo at first appears to have no neck. The heart is as yet, where in fish it remains permanently, in the neck. As the parts of the throat are developed, the lateral processes of the cervical vertebræ grow, and the heart sinks into the chest. The ribs appear in the sixth week as white streaks in the walls of the chest. Their ossification, which goes on rapidly, begins at the commencement of the third month. The sternum is short in the eighth week, and consists of two parts, the ensiform cartilage one, the handle and body the other. Ossification begins in the handle in the fifth month by two nuclei, one above the other. The upper segment of the body soon after ossifies, and generally from one point; the following shortly after, and often from two points: the next, in the sixth to the eighth week; the lowermost in the ninth.

The diaphragm begins to appear in the third month, as a thin membrane without fibres: these are first seen in the fourth month: the tendinous part for a long time is disproportionately large. The parietes of the abdomen are a transparent membrane in the sixth week; in the seventh this membrane becomes opaque. The opening of the navel, at the beginning of the second month is at the lower part of the trunk: it rises as the hypogastric region becomes developed.

The integument, the outermost fœtal product of the serous layer, does not acquire a proper strength till the middle of the fœtal period. The epidermis shows itself at the end of the second month. The rete mucosum does not begin to appear

till some days after birth. At the end of the fifth month the body is covered with a fine covering of short, whitish, silky down, or lanugo: this begins to disappear in the seventh month. The hair of the head and of the eyebrows appears in the sixth month; at the same time the nails are formed. About the fifth month there appears upon the body a yellowish-white greasy substance, at first thinly spread, afterwards increased to a considerable quantity. This is called the vernix caseosa: it is insoluble in alcohol, oils, or water; but some alkalies dissolve a part of it, and form with it a kind of soap: it is found on the surface of the child alone.

The limbs are formed originally below the skin, which they reach, pushing out like little globular shoots, in the sixth week. Even when their completion is considerably advanced, the upper parts of the humerus and of the femur have not obtained a cylindrical covering of skin, but are still below it. This condition, by an arrest of development, becomes sometimes permanent in man, and it is usually permanent in mammalia. When the fingers are first formed they are contained in a common mitten of skin, which gradually becoming thinner between them forms a web, which is finally absorbed.

In vertebral animals the production of the limbs takes place in the following manner. The interior jelly, when it has attained a certain length, divides itself into two parts; an upper or cylindrical part, a lower or flat part. The cylindrical part then divides into arm and fore-arm, thigh and leg; coeval with this separation is the commencement of synovial membranes, capsular membranes, and ligaments. The segments of the limbs are thus formed by spontaneous division, not by the growth of one upon another. Hence it follows, that any intermediate part or segment may be left out, and the limb be deficient either in the bones of the arm, or in the scapula, or in the wrist bones.

The limbs are originally very much alike, and distinguishable only by their situation. In the newly-born kangaroo the arms are as large as the legs. In batrachia the abdominal limbs have the earliest growth: in fish the pectoral limbs on the other hand have the advantage, with an evident reference to their importance to the animal.

In the human embryo the arms are developed earlier than the legs. The swelling in the spinal marrow corresponding

with the origins of the brachial nerves is greater than that for he crural nerves. The clavicle ossifies in the seventh week, and is for some time the largest bone in the body, being four times as large as the thigh. The scapula ossifies soon afterwards; the hip-bone not till the fourth month. At this time the pelvis is small, while the shoulders are fairly spread out. The shoulders are, at the end of utero-gestation, four and a quarter to four and a half inches broad; while the breadth across from one trochanter to the other, is but three and a quarter to three and a half. The femur in the eighth week is entirely below the skin, while the upper-arm is already detached. The carpus ossifies earlier than the tarsus, and the fingers divide themselves and ossify earlier than the toes. Nevertheless, the epiphyses at the knee and the os calcis ossify earlier than the brachial epiphyses and the tarsus. At the fourth month the inferior extremities are as strong as the upper, and acquire by the fifth month more muscular substance than the latter; the hips enlarge, the thigh becomes more fleshy, and the calves are formed. When the muscles become developed, the limbs become bent in consequence of the greater force of the flexors. The limbs originally grow straight out from the trunk. The upper arm then is laid against the breast, the fore arm drawn upward: the thigh is bent up to the belly, the leg drawn backwards towards the thigh, and the feet turned in. The digits in the ninth week are spread out, in the twelfth closed. As the hands are laid upon the neck and under part of the face, so the feet are crossed, with the soles turned inwards.

When an ovum of any magnitude is examined, the embryo is seen suspended by the umbilical cord, and floating in a liquid contained in a loose bag, which is called the amnios. The present is perhaps the best occasion for describing the origin and nature of the amnios.

The amnios is a shut sac resembling a serous membrane, and is the outermost product of the serous layer of the germinal membrane. To form this sac a membrane is reflected from the sides and from either extremity of the embryo, so as to enclose a space behind its frame. This does not take place, according to Velpeau, till after the twelfth day: up to that period, in the human embryo, the amnios has no existence. Towards the eighteenth day the same author found it as a bladder, three

lines in diameter, placed upon the back of the embryo, and continuous with its ends and edges.

As the walls of the trunk close in front, the circle at which the amnios is attached to the body of the embryo becomes proportionately contracted. It is finally limited to the edge of the umbilical opening. At this point it begins abruptly where the cutis and epidermis terminate; and having invested the umbilical cord, it spreads out from the placental end of the latter into that ample sac, as which its appearance is familiar to every student of physiology.

II. The inner or mucous layer of the germinal membrane is supposed, upon the analogy of its office in oviparous animals, to form in mammalia likewise a sac containing a yolk. Now in the chick, while the inner or mucous layer of the germinal membrane is on the one hand expanding over the yolk, it is observed on the other to become curiously contracted towards the body of the embryo into an oblong chamber, which is of course open to the general vitelline sac. This chamber extends the whole length of the embryo as a furrow. *It represents the future alimentary tube;* and hence the term intestinal vesicle is given to the entire pouch out of which it was taken, and of which it now forms a partially-separated chamber.

This furrow or rudimental alimentary canal acquires, by the growth of its sides, at first the shape of a canoe or wherry, either end being bent forward by the inclination of the head and of the caudal extremity. The open furrow has then its sides drawn together so as nearly to meet, except in the middle, where both ends communicate by a common opening with the vitelline sac. At this point likewise, by a central elongation and projection of the canal, both parts point forwards to the common opening, one part representing the upper, the other the lower half of the alimentary canal. Finally, the two canals are completed by the closing of the linear furrow: they remain, however, open towards the vitelline sac, as already described, and the neck of communication is elongated.

In the relation of the intestinal vesicle in birds to the yolk and to the alimentary canal, three points especially deserve attention. 1. From the great size of the yolk, the mucous layer has not extended itself round it, when the formation of the furrow representing the future alimentary canal is required to begin. 2. The communication between the yolk and the ali-

mentary canal does not become interrupted: but, 3dly, towards the close of incubation the yolk-bag is drawn into the belly of the chick, that its contents may be used as nourishment.

Now in mammalia, in which a different provision is made for the nutrition of the mature embryo, a *quantity* of fluid equal or proportionate to the yolk is not needed. Accordingly, the ovum of mammalia is cast in the smallest mould, and the primitive trace is formed on a diminutive vesicle. That vesicle, however, is supposed to contain a yolk, and that yolk to be enclosed within an extension of the mucous layer of the germinal membrane. If this supposition be just, and it is founded upon a strong analogy, the vitelline sac in mammalia displays this remarkable difference from that in birds—it enlarges with the growth of the embryo. In man it attains a diameter of six lines.

The discovery of the intestinal vesicle in mammalia was made by Bojanus. He found in the ovum of the sheep a sac communicating by a neck with the intestinal canal.

A second point of difference in the intestinal vesicle of mammalia from that of birds is, that the tube of communication between it and the intestine early becomes obliterated. The obliteration takes place, according to Velpeau, in the sixth week. Through this circumstance it was that the nature of the intestinal vesicle in mammalia for a length of time escaped discovery; for its existence as a small isolated sac under the name of vesicula alba was well known to anatomists; and Hunter had even seen it filled with the same fluid as the alimentary canal, but connected to it by an impervious thread.

In a remarkable specimen, in the museum of the Middlesex Hospital, prepared by Mr. Sweatman, to which I have already adverted, and shall again advert, the connection of the vesicula alba with the alimentary canal is beautifully shown. The vesicle lies immediately without the amnios; the whole length of the thread leading from it is an inch and a quarter; the length of the umbilical cord is $\frac{22}{50}$ of an inch: the vesicle is pear-shaped, $\frac{11}{50}$ of an inch in its long diameter, $\frac{8}{80}$ across. The filament of the vesicle joins the duodenum close upon what seems the pylorus, or at about $\frac{1}{80}$th of an inch from it. It is supposed that this embryo was about two months old at the period of the sudden death of the mother.

The third and final point of distinction between the intestinal vesicle in mammalia and birds is, that the vesicula alba in the

former, instead of being in the end drawn into the body of the embryo, as happens in the chick, remains without it in the membranous appendages of the ovum, and finally wastes, and disappears by the third month.

We may now trace the development of the alimentary canal. The mouth becomes open in the sixth week; the anus at the seventh. The source of the imperforate anus becomes thus apparent.

The mouth at first is a long transverse fissure without lips: these appear in the ninth week. The tongue begins to be formed in the seventh week: in the ninth week it is large, broad, cylindrical, and projects out of the mouth, into which it is withdrawn in the fourth month; at the same time its papillæ appear. The palate is formed of three pieces on each side, which unite in the twelfth week: the soft palate is constructed in the same manner of lateral parts; hence the congenital malformation, consisting in fissure of the hard and soft palate.

The stomach, as the alimentary canal lengthens and unfolds itself, is at first vertical and cylindrical, and scarcely distinguishable from the œsophagus and intestine. In the ninth week, however, its fundus begins to project to the left side, although as yet its left edge is part of a straight line continuous with the œsophagus and intestine. At the end of the third month the pyloric extremity developes itself, and the viscus is disposed obliquely across the spine. In the fourth month the constriction at the pylorus begins to appear.

The small intestine is the part of the alimentary canal with which in all vertebral animals the yolk sac communicates. According to Burdach this communication takes place *not at the commencement as above stated,* but at the middle of the small intestine; and in mammalia it is situate at a point even nearer to the great intestine. The small intestine is at first of the same diameter with the great: it then becomes larger: it afterwards contracts in proportion as its calibre increases in length. The small intestine is besides originally shorter than the great, but it soon acquires its proportionate length, or even exceeds it.

The great intestine becomes at first proportionally longer and larger than in the adult. The cæcum begins to appear at the seventh month as a small projecting sac, marking the distinction between great and small intestines.

The appendix cæci vermiformis appears in the seventh week, at first it is as large as the small intestine, and proportionately longer than in the adult. At the fourth month it becomes narrower and contorted. The transverse sacculation shows itself in the colon at the end of the fifth month.

The alimentary canal at first consists of an uniform, soft, granular substance, which gradually separates into two layers, the mucous and the muscular. The villi, according to the observations of Meckel, are formed in the following way. The inner surface of the alimentary canal is raised into fine longitudinal ridges of mucous membrane: these at the commencement of the third month become indented or toothed at their unattached margin; the projecting points are the villi. In the fourth month they are proportionately larger than in adults. Although developed both in the stomach and small and great intestines, yet even in the third month they are visibly shorter and smaller in the latter; and by the eighth month they have disappeared.

The valvulæ conniventes do not appear before the seventh month, and till the time of birth they are confined to the upper part of the small intestine.

In the preceding brief description of the development of parts of the alimentary canal, the mucous tube has been represented as elongating itself here and there into pouches: the fundus of the stomach, the cæcum, the appendix cæci, are parts of this nature. Now the conglomerate glands have a similar origin. We are indeed in some degree prepared for this by the structure of the glandulæ muciparæ in the higher animals; and by finding the pancreas in fish, and the salivary glands and biliary organ in articulated animals no more than pouches communicating with the alimentary tube.

The following is the manner in which the salivary glands are developed. A small mass of primitive matter is seen adherent to a part of the alimentary canal: into this one or two tubes, which communicate at their origin, extend from the mucous canal. The blind end of each tube is dilated into a spherical pouch. From the sides of each tube other tubes grow out, of similar character to the first. At first there is no difference in the appearance of the tubes, and their terminal bulbs; but after a little, the latter thickening become of a milk-white colour, the former a clear opal. In this manner the structure

of the entire gland is completed. The proportionate size of the tubes and bulbs is greatest at first. According to Burdach, in sheep and swine the pancreas appears the first of the salivary glands, then the sub-maxillary, and afterwards the parotid: the two former appear at the same time with the thyreoïd, and something later than the liver and spleen. There is this difference in the structure of the parotid and of the pancreas which has an evident relation to the shape of each: in the latter the tubes are longer, and diverge at acuter angles, than in the former.

The liver is formed in the same manner as the pancreas, by tubular productions from the upper part of the small intestine. Accordingly in acephalous fœtuses, in which the upper part of the alimentary canal is wanting, the liver is found to be wanting likewise. The liver is formed upon two tubes, which originate out of the intestine. In the crab the two livers remain permanently separate; and in man, at first, there is not that difference in the relative size of the two lobes which is visible afterwards. The liver in the human embryo at the third month is soft and pap-like: it shortly afterwards becomes firmer, granular, dark-red, and even more vascular than it appears to be after birth; probably because, in addition to the blood of the spleen and of the bowels, it receives a supply from the umbilical vein. Its size at an early period is so disproportionate, that whereas in the adult it is to the whole body as 1 : 36, shortly before birth it is as 1 : 18, and at the end of the first month as 1 : 3. In the first month the liver occupies the under half of the trunk, as the heart the upper. In the second month the liver reaches the ilium: it is then gradually elevated by the increasing growth of the lower part of the frame.

The gall-bladder is formed originally like the elementary tubes of the liver by a tubular extension of the mucous surface of the intestinal canal; but not being received into a mass of elementary matter, it enlarges into a simple sac. Between the second and third month it is an empty canal. It slowly changes from the cylindrical figure to that of a pear. After the fourth month mucus is found in the gall-bladder. Bile is found in the alimentary canal at this time; but not in the gall-bladder till the seventh month.

The reticulated folds in the gall-bladder appear in the sixth month. The openings of the ductus choledochus and pancreas are at first at some distance apart, and project into the intestinal

canal. After the fifth month they gradually approximate, and are drawn inwards.

The lungs may be viewed as another expansion of the mucous layer of the germinal membrane: they begin to appear in the chick at the third day, in the human embryo about the sixth week. Burdach conjectures with great plausibility, that the lungs grow from the back part of the œsophagus, and gradually advancing on either side of the aorta, at length surround the latter. Burdach observed the lungs in very young mammalia to consist of a single mass, in which the rudiments of the bronchi were contained. Through the middle of this mass, however, a spongy partition of membrane could be traced. The separation of the lungs into two begins from behind by the absorption of the layer of membrane above described. A strong bridge of communication is thus left in front of the lungs, which remains for some time, and in which the divisions of the windpipe are contained. While the lungs are being developed, this commissure remains spongy and membranous: it is finally absorbed. The lungs are perfected first at the back part. The lungs at first occupy the lower and back part of the chest; being placed below the heart: they gradually extend forwards and upwards, so as at length to cover the heart. Their weight, according to Meckel, at the tenth week, compared to that of the whole frame, is as 1 : 25 or 27, in the twelfth week as 1 : 43, in the seventh month as 1 : 75. They grow rapidly upon their first appearance, and are then specifically heavier than afterwards.

The surface of the lungs in mammalia is at first smooth, but afterwards is raised into wart-like elevations. These elevations, which mark the future lobules of the lungs, become gradually less prominent. Before their appearance, Meckel observed the furrows to be traced by which the lungs are eventually divided into lobes. In very young embryos, Burdach found the lungs to consist of a thick and homogeneous jelly. In embryos something older, the same physiologist found the original jelly of the lungs interspersed with small firm corpuscles, with their base outwards, and their points turned inwards and adhering to the branches of the windpipe. These corpuscles soon after their first appearance become hollowed into cells, their numbers increase, the jelly which unites them becomes a close and filamentous tissue, and is permeated by increasing bloodvessels. The lungs, at first white, assume a shade of red in

the fourth month. In the sixth month they allow air to be blown into them.

The windpipe in mammalia appears originally of a soft texture, and is flat. Its walls are thick in proportion to the cavity. The first appearance of the windpipe in the human embryo is in the sixth week. The first trace of cartilage in its texture is formed, according to Fleischmann, in the eighth week. Burdach remarked, that each ring of the windpipe is formed of a single cartilage, and that the cartilage forms first in the middle of the future rings, and gradually lengthens towards the ends. The bronchi are short at first; their cartilages appear something later than those of the trachea. Fleischmann is of opinion, that the cartilaginous rings of the trachea are formed of two lateral portions united afterwards in front, at which part he describes the cartilage as for some time thinner than at the sides.

The larynx in mammalia is at first spherical, and consists of an homogeneous jelly. About the seventh week the cartilages begin to appear. The first to be seen are the thyreoïd and cricoïd; and, according to Fleischmann, these are each formed in two halves. The two plates of the thyreoïd coalesce in the fourth month, the halves of the cricoïd somewhat later. At this time the horns of the thyreoïd cartilage and the arytænoïds appear: the epiglottis probably appears a little earlier. The chordæ vocales and arytænoïd cartilages are developed in one thick mass of substance, which at first reaches above the top of the thyreoïd.

From the account which I have given of the origin of the lungs, as well as of the liver and salivary organs, it is evident that to call these parts a production of the mucous layer is a bold and scarcely allowable figure. They are, it is true, formed in a strict relation to the mucous membrane of the alimentary canal, with which their cavities are from the first continuous; but they are directly developed in masses which are spontaneously formed in the embryo, like the original jelly from which the skeleton arises. The correctness of the view becomes the more apparent, when we trace the history of the remaining parts of the glandular system.

The kidneys are preceded in the embryo by a substance first remarked by Wolff, to which the term of Wolffian bodies or false kidneys was given by Rathke.

Burdach, who investigated the nature of these parts in

snakes, lizards, fowls, swine, sheep, and horses, found them to exist at a time when the heart and alimentary canal were the only other occupants of the cavity of the trunk. The false kidneys form at that time a thick mass of jelly-like substance, which is at first simple, but afterwards on the development of the aorta becomes divided at the median plane into two lateral portions. The false kidneys extend originally in all other vertebral animals (like the true kidneys in fish and batrachia) the whole length of the spine, from the heart to the end of the intestine. They gradually shorten at both ends, and at the same time acquire thickness and breadth. This change in form takes place, both in rapidity and degree, in a strict proportion to the rank of the animal in the ascending scale of organization.

In mammalia the false kidneys acquire their greatest relative thickness before the middle of fœtal life; in birds about the middle; in the higher amphibia some time before that period. They then continue to grow exactly in proportion to the rest of the body; after a time, however, they diminish by absorption, and at length entirely disappear. The time of their disappearance is in proportion to the earliness of their production. They disappear something earlier in the female than in the male. They have entirely vanished before birth in mammalia. In birds the right false kidney begins to shrink before the left has reached its full size, and has disappeared entirely at a time when the left is of considerable magnitude. In oviparous vertebral animals a slender tube leading to the cloaca, and termed a false ureter, is temporarily found. Nothing parallel to this has been found in mammalia.

The false kidneys consist originally, like the true kidneys in fish and batrachia, of parallel plates alternately thick and thin. In each thick plate a vessel arises, which, having coalesced with others, in birds and amphibia opens into the false ureter, and in mammalia at a later period opens into the vas deferens or the Fallopian tube. The tubes themselves collect into fasciculi, and form many glandules of an oval or triangular form. The false kidneys are the most vascular parts in the embryo after the liver: four or five branches from the aorta are distributed to each, and two veins are returned from each to the vena cava. The upper vein with an artery are converted into the emulgent vessels, the lower into spermatic vessels.

The false kidneys resemble, as it has been said, the permanent kidneys of fish and batrachia. In the higher vertebral animals they are used to contribute to the development both of the kidneys and of the testes and ovaries.

The true kidneys are formed upon the false. They appear in the human embryo in the seventh week. They acquire considerable size in fœtal life, being at the time of birth to the whole body as 1 : 80; whereas in the adult they are as 1 : 240. In the ninth week they are slender, elongated, and formed of little nodules, which gradually unite together, so that in the tenth week abont eight lobules are observable. These nodules increase in number, and at the time of birth as many as fifteen are distinguishable upon the surface. The ureters appear to stretch from the kidneys to the bladder, having been met with in malformations as blind tubes, not having yet reached their destination.

The renal capsules appear in the chick on the twelfth day. In the human embryo, at the seventh week, they are larger than the kidneys: at the fourth month they equal the latter in size: in the sixth month they become relatively less, and their weight to that of the kidneys is as 1 : 25, in the tenth month as 1 : 3, in adults as 1 : 28. At first the renal capsules touch each other: at nine weeks they become gradually separate, and consist of granules which are collected in three or four lobuli, each of which is supported on a vessel as on a stalk. In the fourth month the corpuscular structure becomes less distinct, and in the sixth the renal capsules separate into an outer greyish substance superficially furrowed, and an inner whitish or reddish substance containing cells in which a yellowish, brownish, or reddish fluid is found.

The spleen appears later than the renal capsules. It is seen first in the human embryo at the tenth week as a small whitish body pointed at both ends: it gradually becomes tinged with red. It is placed further forward in the embryo than after birth. Its size is relatively much less than in adults. According to Heusinger, the size of the spleen at the tenth week to that of the liver is as 1 : 500, in the tenth month as 1 : 50, in adults as 1 : 5; to the whole body, at the tenth week, as 1 : 3000, in the adult as 1 : 180.

The thymus appears in the human embryo about the tenth week as a small body in the upper part of the thorax. It is

formed of two lateral halves, which are subsequently united by cellular membrane. It is for some time as large as the lungs. Sir Astley Cooper has recently shown each lateral lobe of the thymus to be a congeries of hollow corpuscles, which open by single orifices into a common reservoir containing a peculiar fluid. The thyreoïd gland appears at an early period: it consists originally of two separate halves, which grow together in the fourth month, and are proportionally larger and more vascular than in adults.

The mammæ are supposed to be produced by tubular inflections of the skin, as the abdominal glands are formed by tubular productions of the mucous layer.

The bladder and urethra, with the external organs of generation, are formed in part out of a development of the extremity of the intestine, in part by fissure and folding of the integument.

In mammalia, as in other vertebral animals, the allantoïs remains for a time continuous with the extremity of the alimentary canal; so that the last part of the bowel is thus a cloaca, the common termination of the intestinal and vesical apparatus. The sides of this cloaca gradually approach each other, and two folds are thus produced, which at a later period become united, and thus separate the rectum from the urinary canal. The urethra is likewise formed by a folding of the cloaca. The urethra is never closed, but is open from the first and always.

The bladder in the seventh week is an oval corpuscle: in the ninth week it is long and cylindrical, and preserves more or less this form during the rest of the fœtal period. It is formed out of the allantoïs.

The vagina is proportionately longer in the embryo than in the adult. In the sixth and eighth month it is wider, with stronger rugæ, than afterwards. The hymen appears in the fifth month. The penis and clitoris appear indifferently in the sixth week, like a small corpuscle before the cloaca: in the seventh week the organ is spherical, with a furrow channelled in it. In the tenth week it is proportionately of great size. At the end of the third month the cloaca is divided into the rectum and urinary cavity, and the difference may be distinguished between the penis and clitoris.

The testes and ovaries appear in mammalia about the same time at the inner and fore part of the false kidneys, attached to

them by a fold of peritoneum. In the human embryo at the seventh week they form slender elongated bodies placed below the kidneys, with their inferior ends near to each other.

The testis becomes a greyish homogeneous substance, in which the tubular structure gradually developes itself. The ovary is at first smooth, then nodular on its surface: this appearance is seen in the human embryo at the twelfth week; it vanishes again by the fourth month. The testis, at first oval, is disposed obliquely; but at the third month it is laid vertically, and further apart from its fellow; it is convex in front, concave behind. The ovary, at first oblong, becomes afterwards triangular: in the fourth month it becomes again rounder, and then at its outer end more pointed and oviform.

The ovaries in the tenth week are a line and a quarter in length, one third of a line in thickness: at the same time the testis is a line and half in length, and three-quarters in thickness. The proportionate length of the latter to that of the whole frame in the first month is as 1 : 18: in the ninth as 1 : 40.

The epididymis appears in the tenth week: its greatest proportional size is attained at the fourth month. A corresponding organ is formed upon the ovary, but it soon wastes and disappears.

The testes and ovaries are surrounded by the peritoneum, except at their posterior edge where their vessels enter. From either testis and ovary there descends to the internal ring a membranous process, which in the male is termed the gubernaculum, in the female the round ligament. It passes in either sex along the spermatic passage to the filamentous tissue of the scrotum or labium.

The round ligament, as the ovary gradually descends into the pelvis and is drawn towards the uterus, approaches and finally attaches itself to the latter.

The gubernaculum, which is visible in the tenth week, is originally attached to the vas deferens, and gradually fixes itself to the inferior end of the testes or epididymis. The preceding circumstance explains a most remarkable deviation which I remember to have met with in the body of an adult. The left testis had not descended, and lay upon the edge of the psoas muscle immediately within the internal ring; while the cord, doubled through the persistence of the original attach-

ment of the gubernaculum to it, had been drawn down in a long fold into the scrotum.

The ovaries, originally attached to the loins, gradually descend from their vicinity to the kidneys: they remain for a time placed upon the psoas muscle; they then fix themselves on the brim of the lesser chamber of the pelvis, where they remain for a long period after birth.

Up to this time the progress in development and change of place of the ovaries and testes is much alike, except that the latter are always a little in advance of the former: in the seventh month the testes reach the inner ring; in the eighth they enter the passage, in the ninth the scrotum. Upon an examination of ninety-seven infants at birth, Wrisberg found in sixty-seven both testes in the scrotum, in seventeen one or both in the canal, in eight one testis, and in three both testes in the abdomen.

It is difficult satisfactorily to account for the descent of the testes. The gubernaculum can hardly give the first impulse, for it does not become fibrous till the sixth month, and the testis is then already lowered in its position. The descent is probably a process of growth.

The vas deferens is a production of the epididymis; it is at first directed downwards; about the fourth month it is reflected upwards: it subsequently descends: it is already, in the fifth month, convoluted. The vesiculæ seminales are of slow development; they are productions from the vasa deferentia.

The Fallopian tubes in the higher vertebral animals, in which they are in their origin, and remain afterwards, separate from the ovaries, are supposed to be the last product of the false kidneys. The Fallopian tubes gradually bend themselves, and form a trumpet-like end at the eighth month, when they are more convoluted than in the adult. By the inner extremity either Fallopian tube joins its fellow at an acute angle to form the uterus. The uterus has thus originally two bodies; the neck then is formed, and from thence the single body of the uterus is produced. The uterus is still out of the pelvis in the sixth month. At this period it descends into the pelvis. The uterus at birth is proportionately much larger than during the intervening period before puberty.

III. It has been explained that each organ begins to be developed without blood or blood-vessels. A force of vital attrac-

tion draws together the fitting elements in each part, and it is only for the subsequent growth and perfection of the organs that a circulation is established in them. The heart even is formed and shaped, and its texture has acquired some degree of consistency, and it has begun to display an undulatory motion, before the blood has reached it.

According to the observations of Prevost, Dumas, and Von Baer upon the development of the chick, the following periods are to be observed in reference to the development of the vascular system.

Between the twentieth and the thirty-sixth hour appear, first the vascular area, figured in a preceding page—then the heart—then the formation of blood in the vascular area: but as yet the blood is motionless. The heart is soft, transparent, separating itself into an oblong sac something curved, and a colourless fluid; and about the middle of the second day, that is, about ten hours after its first appearance, it begins to exhibit an undulatory motion, pulsating on its own colourless fluid alone, while there already exists red blood in the circumference of the germinal membrane, that is to say, in the vascular area, which acquires motion independently of the heart.

By the end of the second day or by the commencement of the third a simple circulation is established: the blood finds its way from the vascular area by the omphalo-mesenteric veins to the heart, from which it is expelled along the aorta, and from thence again to the vascular area.

Between the third and sixth day the systemic with the hepatic circulation commences. The aorta distributes branches to the body, and the venæ cavæ are formed, and the vena portæ; so that while part of the blood is thrown through the vascular area, part circulates through the frame. The aorta at the same time forms five pair of branchial branches in the neck.

During the next period the branchial branches shrink, the circulation retires from the intestinal vesicle, but new vessels make their way out of the body of the embryo following the allantoïs.

Finally, this second extraneous circulation is drawn back, and the blood prepares to flow through the lungs.

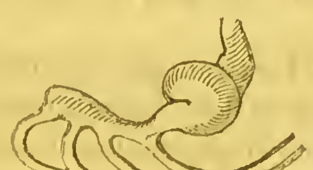
In the embryo of the chick the first vessels which appear are veins, which are developed in the vascular area, and terminate in a circular vein which marks the limits of the vascular area:

this vein is called the vena terminalis or circulus venosus. It is at first a simple channel, in which the blood is being formed, with no distinguishable boundary or coat. Such a vessel Cuvier saw upon the intestinal vesicle of rodentia. In other mammalia it appears to be wanting, or else to vanish at a very early period. The earliest branches of the aorta are distributed to the intestinal vesicle, upon which they radiate, and after many anastomoses terminate in the roots of the veins. In mammalia there is but one omphalo-mesenteric artery and one omphalo-mesenteric vein; the latter is larger than the former. In the chick there are two veins originally, which coalesce in a single trunk, that joins the posterior cavity of the heart. There is now a simple circulation, of which the poles are the heart and the vesicula intestinalis. The venous trunk then divides, one part forming the ascending cava, the other the rudiment of the vena portæ.

All the arteries take their origin from one trunk, which springs from the heart. The heart in all vertebral animals is originally one simple elongated sac. The single artery which rises from it branches into five pair of arches, between which the œsophagus lies.

The single heart and artery, with its branchial arches, are permanent parts in fish: in other vertebral animals they undergo a series of metamorphoses, by which they are successively brought to the characteristic type of each species. The essence of these changes in birds and mammalia is, that the heart spontaneously divides into two separate chambers, the artery into an aorta and pulmonary artery; that some of the arches disappear; others becoming permanent aortic, others permanent pulmonary branches.

The heart of the dog, at the twenty-first day, is a membranous tube twisted on itself, and slightly divided into an auricle, ventricle, and aortic bulb. The wall of the ventricle soon acquires a greater thickness than the rest.



At a period which is probably between four and six weeks, the rudiments of a septum begin to be perceived in the heart. The septum of the ventricles is produced in two ways: on the one hand it arises as a growth from the base of the ventricles; on the other it originates in the extension and growth of the right ventricle in such a manner as render the extremity of the heart bifurcated. This appearance begins in the seventh week.

The external figure which the heart now assumes is permanently retained in several species of mammalia. The heart of the dugong and of the manatee presents in the most characteristic manner this permanent separation of the ventricles. The same is seen in a less degree in the walrus, seal, elephant, and in some of the rodentia.

The internal construction at present has some resemblance to the permanent character of the ventricles of the alligator. But it is most strangely and strikingly preserved in those imperfect human beings, in which from this period a communication between the two ventricles remains throughout life.

The nature of the formation of the inter-auricular septum is very obscure, and requires further investigation. The first appearance of an inter-auricular septum is in the direction of the Eustachian valve, which at that time appears to be continuous with the annulus foraminis ovalis; and thus lying before the entrance of the vena cava inferior, causes it to open into the left auricle. This is seen about the fifth week. At the sixth week this septum becomes perforated by many foramina, and by a process of absorption wastes into the Eustachian valve. At the same time a production analogous to the first begins to be formed in the place of the permanent inter-auricular septum. It is remarkable that it is at this period—namely, when the inferior cava begins to be shut out of direct communication with the left auricle—that the pulmonary veins open into it. The valvula foraminis ovalis goes on increasing till the seventh

month, when it is already a sufficient flap to cover the orifice of communication.

At this period of development it is evident that the fœtus becomes fit for pulmonary respiration. The oblique opening, which serves if the embryo remains in utero to transmit the blood from the right auricle into the otherwise empty left, would it is evident become closed, if breathing and a circulation through the lungs were now commenced, and an equal stream of blood were poured into the left auricle as into the right.

At the time when the aorta gives off its cervical arches, the construction of the adjacent parts participates in the same character, and might indeed more readily be converted into branchial organs than into a higher type. The neck is short and thick, the pharyngeal portion of the alimentary canal is of great size, and its sides are penetrated by clefts.

Four openings on each side of the œsophagus have been observed in the embryo of the dog, between three and four weeks old; in that of the sheep of three weeks; of the pig at three weeks; of the rabbit on the twelfth day; and in the human embryo of six weeks: in the embryo of the dog, some little time before that mentioned above, only three apertures are found. While three pairs of clefts exist in the sides of the pharynx, there are in the dog, as in the chick, only four pairs of vascular arches: but before the first of these becomes obliterated, a posterior or fifth pair is produced, while at the same time the fourth branchial cleft is formed; so that in the mammiferous animal five pairs of vascular arches and four pairs of clefts exist for some time simultaneously in the sides of the neck.

A few days after the appearance of the fifth arch, the neck begins to elongate, the apertures are closed gradually on the outside, and the lower jaw becomes more developed; while the vascular arches undergo those changes by which the permanent arterial branches arising from the heart are formed.

The first and third pair of vascular arches form the carotid and subclavian arteries in mammalia, as in birds; and the second pair seems to be wholly obliterated, or at least gives only a small branch; in mammalia, however, the arch of the aorta, or permanent communicating vessel between the ascending and

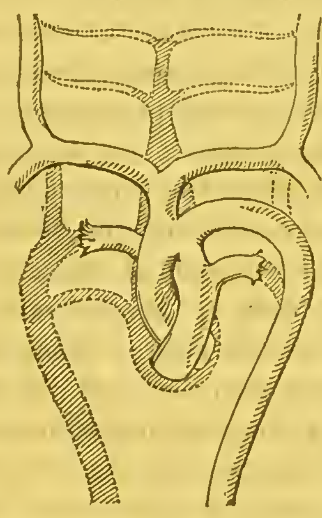
descending aorta, is formed from the fourth branchial arch on the left side of the œsophagus; so that the order in which the vessels of the head and superior extremities arise is reversed, the right innominata taking its origin before the vessels of the left side.

The pulmonary vessels appear to be given off by the fourth arch on the right and by the fifth on the left side, the fifth on the right being wholly obliterated. While, however, the carotid and branchial arteries become developed from the anterior arches, the pulmonary arches do not continue to carry blood to the root of the aorta, as takes place in those of the bird. The parts by which these arches communicate with the root of the descending aorta (forming in birds the ductus botalli) become gradually obliterated; so that of all the five pairs of vascular arches in the embryo of the mammiferous animal, only one, the fourth of the left side, remains prominent.

While these changes take place in the pulmonary arches, the bulb of the aorta, from the single cavity of which the pulmonary and systemic vessels arise for some time in common, is divided, so as to form the roots of the aorta proper and pulmonary arteries. According to Meckel, the septum which has separated the left ventricle entirely from the right, appears to be continued onwards into the bulb of the aorta, and thus separates this cavity longitudinally into two compartments. The division of the bulb is, however, imperfect for a time; it advances gradually from the part next the ventricle to that from which the vascular arches rise; so that, while the posterior part is divided, the anterior yet remains single, a communication being left at this part between the aortic and pulmonary roots, which admits of the passage of the blood from the right ventricle into the aorta, when the pulmonary arches are obliterated. When the division of the aortic bulb has just taken place, the arch and descending part of the aorta appear to be a continuation of the pulmonary rather than of the aortic root, the latter appearing to lead only into the vessels of the head and anterior extremities. The ductus arteriosus remains for some time, as at first, short and wide, and has the appearance of being an opening of communication between, or a deficiency in the parietes of the juxtaposed tubes; it afterwards becomes lengthened out and narrowed, and appears during a short period to pass from the aorta to the pulmonary root and aorta conti-

nuous with it; but about the tenth week in the human embryo this part is dilated, and forms a more direct communication between the ascending and the descending aorta, and the ductus botalli is now formed by another part, *viz.* the end of the pulmonary root leading into the arch of the aorta.

The following diagram from Burdach may assist in illustrating the description which has been given of these changes; the parts of the figure left in shade represent the single original artery, and those branches derived from it which shrink in the progress of development: the parts fully figured show the division of the primitive trunk, and the persistence of some of its branches as aortic, some as pulmonary arteries.



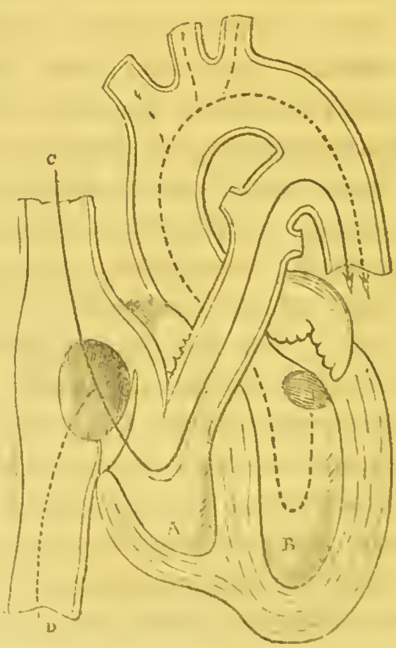
The lungs of mammiferous animals do not appear to be visible before the period when the branchial apertures begin to close. As the lungs become larger, they receive vessels from the pulmonary arches, which gradually enlarging as the fœtus becomes developed, divert the stream of blood from the arterial duct of the aorta. This latter opening now diminishes in size, and at birth, when the afflux of blood to the lungs is suddenly increased, it gradually closes.

The metamorphoses which have been described in the organs of the circulation have relation to three important principles. The first is that wonderful law of development, agreeably with which it has pleased Nature to pass the highest animal forms through the moulds of the lowest, and to require the mammiferous animal first to put on the garb of a fish, then of a reptile, then of a bird, before finally assuming its proper type. Is

it presumptuous to expect from what has been already gained in so short a time, that a clear light will thus eventually be thrown upon the rules by which creation was governed in the progressive scheme of animated Nature?

The second principle is the production of a series of parts, which shall be easily convertible into organs of a double circulation: so that at the period of birth, the order of this function may be at once recast upon a new plan.—The heart to be two, not one, each receiving and propelling a different fluid, and for different purposes; the right heart receiving black blood from the body, and transmitting it to the lungs to be renovated; the left heart receiving the purified blood from the lungs and transmitting it through the entire system to sustain life and furnish the materials of growth.

The third principle is the preservation (during the whole period that the fish-like or simple heart is being converted into a double organ) of the means of a single circulation. It is the necessity of maintaining the fœtal circulation as a single circulation up to the moment of birth which produces the apparent complexity of these parts and seeming clumsiness of action during the last seven months of fœtal existence. Two hearts are gradually forming out of one: two arterial systems out of one arterial system; from two distinct sources different streams of blood arriving at the heart; but the two are as yet to be mixed, and to reach eventually the same vessel, and to be distributed similarly and together for all the purposes of the fœtal frame.



The adjoined diagram may assist in enabling the reader to follow the description of the fœtal circulation which has to be introduced in the present place. In the diagram, A represents the cavity of the right ventricle, B that of the left.

Blood reaches the right side of the fœtal heart from two sources. That which is conveyed into the right auricle, by the

upper cava and the coronary vein, is blood that is returned from nourishing the head and upper part of the body and the heart. In the diagram this stream of blood is represented by the continued line C. That which flows into the right auricle by the lower cava (represented in the diagram by the interrupted line D) is not merely blood that has been circulating through the lower part of the frame, but consists in addition of blood returned by the umbilical vein into the body of the fœtus: the latter quantity of blood again has arrived in two ways; for the umbilical vein, after entering the navel, and passing in the round ligament to the under surface of the liver, divides into two branches; one only of which, called the ductus venosus, goes straight on to join the cava, at the posterior margin of the liver: the other goes to the portal vein of the liver, into which it opens, and pours its blood; which has thus to pass through the complete circulation of the liver, before, issuing from it by the hepatic veins, it at last can pursue the first portion into the inferior cava. The stream of blood D thus consists of blood returned from nourishing the lower part of the frame, of blood derived directly from the umbilical vein by the ductus venosus, of blood that was poured into the portal veins by the umbilical, and has gone through the circulation of the liver in mixture with the other blood of the portal vein.

These two streams of blood on entering the right auricle pursue different routes, which it is extremely interesting to trace. The stream C, transmitted by the upper cava, rushes through the auricle into the right ventricle A: at least this is fairly presumed to take place in the living fœtus, because in anatomically preparing the fœtal heart and injecting it, it is found that wax thrown into the upper cava pursues this course. The direct channel into the right ventricle is therefore from the upper cava; that is to say, when the right ventricle expands, it directly draws towards it the contents of the upper cava. The line continued from C marks the further progress of this stream of blood. Expelled from the contracting ventricle it enters the pulmonary artery: the pulmonary artery distributes two as yet insignificant and nearly impervious branches to the lungs; its main channel is continued under the name of ductus arteriosus directly into the aorta below its arch, and we may suppose the stream of blood from that point to be bent down the channel of the descending aorta

But the descending aorta after a short course divides into the two common iliac arteries; and the common iliacs again divide into the external and internal iliacs; and almost the whole of each of the latter is consumed to form the so called umbilical artery, which carries blood away from the body of the fœtus, by the navel string to the placenta. But the stream C, which so rapidly passes towards the iliac vessels, the reader will observe, is blood that has been circulated through the systemic capillaries. Whatever vivifying or renovating influence the placenta can give, it must be in need of, and it accordingly passes with wonderful directness towards that vessel.

The stream of blood D pursues a different path. The Eustachian tube, a crescentic fold of membrane, the half of which (that would remain) is faithfully represented in the diagram, is so disposed as to turn the current of D on its entrance into the right auricle away from the ventricle A, and to direct it towards the foramen ovale, which leads into the left auricle. Injections on the dead subject verify the correctness of this hypothesis. The stream of blood D having thus reached the left auricle is thence drawn into the left ventricle B; from thence it is propelled into the aorta, and is in part distributed through the great branches which rise from its arch to the head and upper extremities of the frame. It would have been reasonable to anticipate that so important an organ as the brain would have a considerable supply of the fresh draught of blood from the placenta: and the preceding statement shows this to be the fact. It is well known that the head and upper extremities of the fœtus are forwarder than the legs; how far may this be attributable to the greater supply of placental blood which the former parts receive? The residue of the stream D makes its way down the aorta towards the pelvis: mixing with the stream C at the arch, it supplies it with a proportion of placental blood for the growth of the lower limbs: but the stream which flows thither is the same from which the draught out of the body takes place along the umbilical arteries to the placenta.

Let me now recapitulate the principal heads which have been illustrated in the present section.

The ovum of mammalia is at first two sacs, one enclosing the other: the inner containing a liquid. Upon the inner, or below it, the germinal membrane is seen, with the primitive trace. The germinal membrane expands and divides into two

layers, the outer or serous, the inner or mucous: then a third is developed between the two first, which is the source of the vascular system. The serous layer developes in itself, the bones, joints, muscles, the brain and nerves, and the organs of the senses, together with the integument, and reflects from the contracting opening of the trunk of the enlarging embryo the amnios, as a bladder, at first covering its dorsal surface and sides, at last a capacious sac, in the fluid of which the embryo hangs and floats.

The mucous layer may be supposed upon analogy to expand into a sac containing the yolk; then by its contraction first and elongation afterwards below the body of the embryo, it forms the alimentary canal, and by its tubular productions contributes to originate the glandular system and the lungs. The first appearance of the vascular system, or the first development and expansion of the vascular layer, takes place upon this membrane in the circle called the area vasculosa. The second step in the development of the vascular layer, is the production of the heart and aorta, and the growth from the aorta of branchial branches. As this second step, as well as the first, seems to have some reference to a respiratory function, so has it likewise a relation to the development of the mucous layer. The third step, like the two preceding again, is an attempt to establish a respiratory organ, and it is again equally performed through the assistance of the mucous layer.

It is this point at which we have now arrived: we have seen in the human embryo how rapidly the vesicula intestinalis shrinks and is lost; how quickly the branchial arteries are metamorphosed. We have now to trace the production of the true respiratory organ of the embryo; or, more than that, of its common source of increase and breathing.

The lower end of the alimentary canal, or cloaca, shoots out a sac, which is termed the allantoïs or allantoïd membrane. In the chick on the third day, the end of the alimentary canal extends itself into a spherical bladder, which by the following day is divided into a channel leading into the cloaca and the proper allantoïd sac. After a short period, the terminal branches of the aorta with corresponding veins are seen upon this sac. The sac then protrudes more and more out of the body of the chick, tending to the surface of the egg. It spreads from the right side of the chick, first towards the pointed extremity,

then towards the rounded end of the egg, so as at length to form a double sac laid immediately under the membrane of the shell, upon which the blood-vessels are distributed with the evident purpose that their contents may be influenced by the atmosphere through the porous egg-shell and its membrane, and that thus a true respiratory organ may be established.

The allantoïs exists in all mammalia. It appears later necessarily than the intestine which forms it, later than the heart, the liver, and the Wolffian bodies. It contains from the first a liquid. In the human embryo it appears in the fourth week.

The allantoïs grows rapidly; but in man it attains a trifling size only, then wastes. In other mammalia it acquires a greater amplitude. In carnivora, in solidungula, and in ruminantia, it grows to such a magnitude as to enclose the whole amnios. In rodentia and in swine it is of less extent, and covers part only of the amnios. The channel of communication between the allantoïs and the cloaca or bladder at first is short, so that the former lies directly against the body of the embryo. It is afterwards much elongated, like the corresponding channel of communication of the vesicula intestinalis. In mammalia in general the allantoïs continues during the whole period of fœtal existence: but in man its duration is so short, that it has almost disappeared by the sixth week. The urachus is the remains of the channel of communication with the now obliterated sac. The younger the embryo, the larger is the urachus. Hunter traced it the whole length of the umbilical cord. Commonly the urachus at the fourth month is pervious for a few lines only from the bladder, being closed towards the navel, and vanishing in the cord. However, it sometimes happens that its origin is for a short extent permeable even at birth. Burdach and Roderer concur in stating, that they had met with in the mature fœtus a sac containing fluid, not then communicating with the urachus, but which was probably the allantoïd sac.

The origin of the navel-string, or umbilical cord, may be understood by referring to what has been already stated of the allantoïs and of the amnios. The allantoïs stretches from the cloaca to spread itself as a sac upon the outer surface of the amnios. As it enlarges, its portion of communication with the cloaca shrinks to a narrow tube that speedily becomes impervious. As it shrinks, the amnios closes upon it, and follows it, and thus forms a cylindrical tube. In the middle of this

shrunk tube of communication is the urachus: these parts, with the umbilical artery and veins, and a connecting gelatinous tissue, form the navel-string.

The navel-string is visible in the human embryo in the sixth week, as a short and straight cord. In the ninth week it is longer and proportionally thinner, and no longer transparent. The arteries in it are thicker and smaller than the vein, which is disposed in the axis of the cord with the arteries spirally wound round it. In twenty-eight out of thirty-two instances, Hunter observed that the spiral of the vessels turned from left to right. As the cord lengthens, the vein as well as the artery, and even the cord itself, becomes spirally twisted. At birth, the length of the cord is on an average about two feet; but it varies from one foot to four. When very long, the umbilical cord is generally twisted round the child's neck: it has been known to have been so twisted four times and a half. This accident does not appear to affect labour, except in cases in which the child is turned.

The outer tunic of the cord, or the amnios, is a genuine serous membrane with a glossy internal surface. It begins, as it has been already stated, in the closed embryo abruptly at the navel, contains in its tubular part the cord, and then forms a loose reflected sac never tensely filled. The fluid which it contains is transparent, and without any sensible degree of tenacity or ripeness; sometimes it is foul or muddy, with something of a yellowish cast. The proportion of fluid is greater in the earlier months. Its actual quantity at birth is variable, averaging about two or three pints, but varying from one pint to some quarts. Its composition is as follows:

Water	98.8
Albumen, muriate of soda, soda, phosphate of lime, lime	1.2
	100.0

The umbilical arteries and veins stretch through the cord to something placed without the amnios. Their destination is the outer membrane of the ovum, within the cavity of which all the changes which have been hitherto described take place. This outer membrane is called the chorion.

The chorion at the end of the first and during the second month has a villous external surface. At the end of the second month, the branches of the umbilical vessels penetrate and

ramify in these villi, which become partially or wholly intensely vascular; the umbilical arteries ramifying to capillary minuteness in the villi, and without intervening cells, return their blood by the venous branches to the umbilical vein.

At this time there is a great interval between the amnios and chorion, occasioned by the diminutive volume of the former, which is then a sphere of ⅔ only of the area of the chorion. The interval is filled up with a substance termed the corpus reticuli or vitri by Valpeau. It consists of delicate but not very slender gelatinous threads, between which a liquid is probably contained. The vesicula alba lies in this matter. The corpus reticuli disappears as pregnancy advances, and the amnios and chorion come into contact.

SECTION III.

Of the Nutrition of the Embryo, and of the Connection of the Fœtal and Maternal Systems.

The materials, through which the ovum grows at the earliest period, are probably the fluid secretion of the surfaces it rests on, absorbed by its entire superficies. The little sphere thus enlarges in its progress along the Fallopian tube, and upon its first arrival in the uterus. A time follows when a new and special structure is formed, by means of which the maternal circulation is brought into indirect communication with vessels that are produced for that purpose from the embryo.

The organ of communication follows one of two types.

The first of these is strikingly exemplified in ruminants. In this class of animals, circular or oval patches of the mucous membrane of the uterus become elevated into a spongy mass termed a maternal cotyledon. The cotyledon is soft, and highly vascular; and the large pores, which render it sponge-like, open upon its free surface, and extend from thence towards the uterus, against which they terminate as culs de sac.

The following diagram represents a section of a part of the uterus and of one of the cotyledons of a cow.

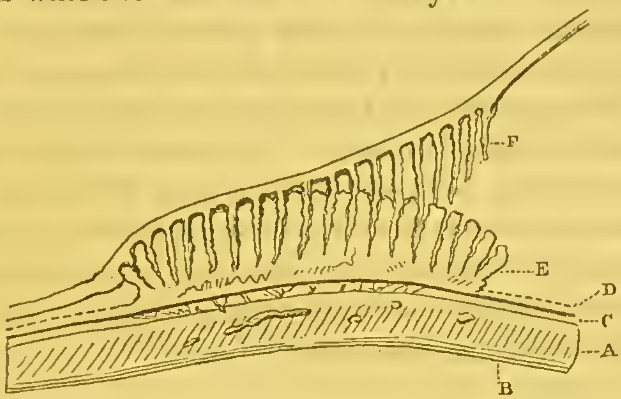
A. Represents the section of the uterus.

B. The peritoneal coat.

C. The sub-mucous coat.

D. The mucous coat, of which

E. Is the section of one of the tubular or sponge-like enlargements which form the maternal cotyledons.



To meet this structure, the chorion forms as many groups of flocculent processes as there are maternal cotyledons. These groups of processes are dovetailed with the pores of the latter. In the figure, some of the processes [F] are represented as drawn out; others, as left imbedded in the pores, with which of course they were simultaneously formed. The term fœtal cotyledon, is given to each of these patches of flocculi.

There are thus brought into extensive apposition and coadaptation maternal surfaces, and surfaces produced from the ovum. But upon the surface of a maternal cotyledon, branches of the uterine vessels ramify to intense capillary vascularity. And upon the corresponding surface of the fœtal cotyledon, branches of the umbilical vessels ramify likewise with the same profuseness of distribution. They do not communicate: they are in contact only. In separating them, I have thought I have observed a sort of milk-like fluid exude in small quantity. No doubt can be entertained, that the fœtal capillaries either imbibe this fluid — a product of maternal secretion — or directly draw nutriment from the blood in the maternal vessels; the process in either case being governed by the endosmose of Dutrochet.

When the ruminant brings forth, the fœtal and maternal cotyledons separate. The fœtal cotyledon comes away with the membranes. Itself a growth of the chorion, it naturally is expelled with the chorion. The maternal cotyledon, a growth from the membrane of the uterus, remains, but gradually shrinks, and is absorbed during the decrease of the uterus.

In the mare, a structure comparable to the cotyledonous structure is met with; but it is not distributed in groups of eminences. The structure is diffused over nearly the whole of the opposite surfaces of the uterus and ovum. The inner lining of the uterus is delicately honeycombed: within its shallow cells, processes of the chorion are contained.

I am disposed to think, that, in all mammalia but the human species, the mode of communication between the uterine and maternal systems proceeds upon this principle variously modified. It leaves, it is evident, no likelihood of serious hemorrhage in labour.

However, I have had no opportunity of satisfactorily examining the impregnated uterus in other animals than the cow and the mare; and I must admit that in several, in the hare and cat for example, the outward appearance of the communicating organ very much resembles that of the organ which is found in human beings — the placenta namely. The *thickened* part is in the cat entirely fœtal, and comes away in labour as in human beings. Nevertheless, the structure of the thickened part does not seem the same with that of the human placenta. Whether it more approach that, or the cotyledonous form, remains to be investigated. My expectation is, that it will be found to be cotyledonous in principle.

In human beings, the provision for bringing into indirect communication the vascular systems of the mother and of the embryo is the following.

The commencement of, or preparation for, it I have had an opportunity of examining, in concert with my friend and colleague Mr. Sweatman, in a specimen recently added by him to the museum of the Middlesex Hospital. It is the uterus of a young female who died suddenly of fright towards the close of the second month of pregnancy, as it is supposed from the size of the embryo, which is ¾ of an inch in length. The uterine vessels of this specimen when recent were injected with tallow, coloured red for the arteries, white for the veins. On opening the uterus so injected on the following day, the arteries and veins were found to be extremely large and numerous: the veins, however, were the most numerous, occupying almost entirely the inner two-thirds of the substance of the womb. But the veins had been injected before the arteries. Much extravasation had taken place into the uterine cavity. On clearing this away, the

ovum was displayed; its outer tunic, the chorion, being characteristically flocculent, but unequally so. Between the chorion and the inner surface of the womb, lay a layer of lymph. This was the normal exudation from the inner surface of the womb, which begins immediately upon impregnation taking place, and continues for some time to be gradually added to. By the pressure it is subjected to, this lymph is early moulded into a membrane, which is called the decidua. The effused layer, in the present instance, had ceased to be of uniform thickness. Towards the cervix it formed a mass nearly one-fourth of an inch in thickness at its middle, and about three inches in length, and in breadth from one and a half to two: elsewhere the decidua was a thin membrane.

It appeared further, that the vessels of the uterus had extended themselves into this membrane; principally, however, at the part where it is thickened. The vessels again, which are seen to have penetrated the membrane, are almost exclusively veins [possibly because they were first injected]: they are of a large size, and end abruptly; or the injection which filled them so ends, having probably at the points of its apparent termination ruptured the tissue, and become extravasated.

Such is the preparation for the production of the communicating organ, which in its completed state is presently to be described. On the part of the uterus lymph is effused, which forms a membrane that becomes thicker at one part than another. On the part of the embryo are the enlarging villi of the chorion, in which the umbilical vessels are being distributed. In the specimen above adverted to, the villi of the chorion are twice as long and thick upon the surface turned towards the thicker part of the decidua, as elsewhere.

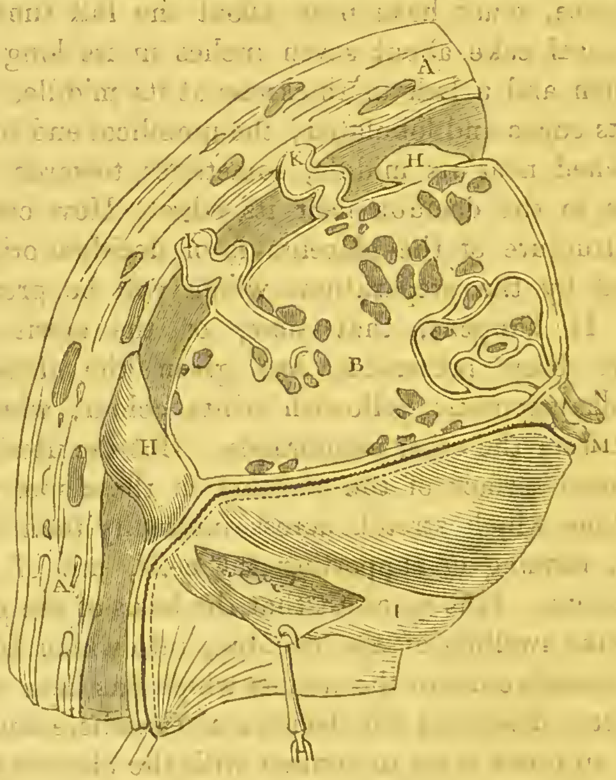
The resultant organ, which the two systems combine to form, is termed the *placenta*. Its structure was discovered by Dr. William Hunter; and although some have called in question the correctness of his views, the evidence in its favour which I shall presently have occasion to mention must, I think, be admitted as satisfactory and decisive.

The basis of the placenta is the bed of exuded lymph forming the thicker part of the decidua already described. It gradually becomes a series of cells: into these cells the uterine arteries pour blood: from these cells the uterine veins return

the blood to the maternal system. There is thus a perpetual flow of the maternal blood through these cells.

But while these cells are thus forming, the villi of the chorion, carrying with them the branches of the umbilical arteries and veins, penetrate and everywhere permeate the spongy tissue. The umbilical capillaries thus become diffused as a network upon the cells of the placenta, which contain maternal blood; and the fœtal blood draws by endosmose the materials of growth from the blood of the mother through the thin intervening membranes.

The following diagram represents an imaginary section of a lobe of the placenta, and the elements of structure above described. The placenta and decidua are supposed to be separated, and drawn to a little distance, from the inner surface of the uterus, so as to display the passage of the veins and arteries.



The parts indicated by the letters are,

A. Section of a portion of the uterus.

B. Section of a portion of the placenta; a *few* cells only figured, for the sake of distinctness.

C. The decidua.

D. The chorion.

E. The amnios.

H. Uterine veins.

I. Continuation of an uterine vein along the edge of the placenta.

K. Uterine arteries.

M. Branch of an umbilical artery.

N. Branch of umbilical vein.

The preceding diagram I made after examining, in concert with Mr. Stanley and Mr. Owen, the preparations of the injected placenta and uterus in the Hunterian Collection at the College of Surgeons. I will now subjoin the description, which I drew up at the time, of the appearances, which we agreed in recognizing in these specimens.

I will premise only that the placenta, which furnished the best evidence, must have been about the full time, when it forms an oval cake about seven inches in its long diameter, and an inch and a half in thickness at its middle, narrowing towards its edges and lobulated; the umbilical end being generally attached near its middle, sometimes towards its edges, sometimes to the decidua near its edge. How certainly the cellular structure of the placenta is of decidual origin is demonstrated by the preparations which will be presently described. It happens, that time, or the spirit in which they have been preserved, has given the decidua elsewhere a characteristic yellowish white colour, which distinguishes it from the other membranes. But the uterine surface and the fœtal surface of the placenta in these specimens, and the partitions which stretch across internally from the one to the other, forming or supporting the cells, are of the same peculiar colour. It is manifest that the basis of the placenta is a sponge-like swelling of the decidua, into which the uterine and fœtal vessels enter in the manner which has been described.

Dr. Hunter described the decidua as elsewhere double, consisting of an inner layer in contact with the chorion called decidua vera, an outer, the decidua reflexa. This distinction is partial only, and [in my belief] an accident, typifying only *elsewhere*, that structure which is developed in the placenta; or evincing a general disposition in the decidua to separate into layers, enclosing or not an intermediate structure. Dr. Hunter supposed that the production of the two layers arose from the

ovulum, on entering the uterus, finding the cavity lined with a membranous layer, one part of which it raised and pushed before it, forming thereby a doubled sac within the other. A little reflection serves to show that this explanation of the appearance is perfectly untenable.

The series of specimens contained in the Hunterian Museum are separated portions of the uterus and of the placenta, at the full time but antecedently to labour. The preparations of both are injected with the same coloured materials. In the portions of the uterus, the arteries are filled with red wax or tallow, the veins with black wax or tallow. In the portions of placenta, the cells are filled, some with the black material, others with the red; and tubes leading to these are seen, some filled with one, some with the other. It is certain, from their appearance, that they must have been injected from the uterine vessels.

The preparation in the Hunterian museum which throws the most light upon the structure of the placenta, and upon the extension of the maternal circulation into it, is marked No. 3535.

The specimen is a triangular portion of a placenta, having a superficies of about four square inches, one of the sides of which is formed by the margin of the placenta, the other two being cut surfaces, the depth of which, at the angle at which they meet, is an inch and a half. It consists of one entire lobe, and of portions of three other lobes of the placenta. Three kinds of wax injection (one yellow, a second red, a third black) have been thrown into it. The yellow wax, which appears to have been injected last, and more sparingly than the others, is seen to be in the umbilical arteries. The sources and place of the black and of the red injection, with the latter of which the portion of placenta under consideration is most coloured, will be pointed out afterwards.

The substance of the placenta is seen to be covered by two layers of decidua, one disposed on its uterine, the other over its fœtal surface: these two layers of decidua meet, of course, and become *one*, at the circumference of the placenta. Upon one of the cut surfaces of the placenta, productions of the decidua are seen extending through the placenta, from the fœtal to the uterine layer of the decidua, which they unite.

Upon the uterine surface of the uterine layer of the decidua are seen orifices of different sizes, some containing red wax,

others black wax. Some of these orifices are upon the surface of the lobes, others at the interlobular spaces. The orifices containing red wax open indiscriminately at either situation. The orifices containing black wax open principally at the interlobular spaces. It may be presumed that the orifices containing black wax were continuous with, and injected from, the uterine veins; and that those which contained red wax were continuous with, and injected from, the uterine arteries, upon the following grounds.

The orifices containing black wax are larger, and lead into larger channels than those which contain red wax. Some of those which contain red wax lead into channels which have the singular tortuous character, described by Mr. Hunter as characterizing the termination of the uterine arteries (see K in preceding diagram). And there is a preparation of part of an uterus, in the same series in the gallery, which there can be little doubt is that from which the specimen under consideration was separated, and in which the arteries are injected with red, the veins with black wax.

The orifices upon the uterine surface of the uterine layer of the decidua lead into flattened tubes of greater or less length, which tubes appear to be regular channels, with smooth internal surfaces, formed in the substance of the productions of the decidua. Of these tubes, those which contain red wax are called, in the following description, *decidual arteries:* those which contain black wax, *decidual veins.*

One large decidual vein runs along the placental margin of one lobe (see I in diagram). Another, of smaller size, passes nearly vertically in an interlobular fissure from the uterine to the fœtal surface of the placenta. The former terminates opposite to an interlobular space at the edge of the placenta, in two small decidual veins: one of these smaller veins opens into the extremity of the vertical interlobular vein just described; the other extends along the fœtal surface of the placenta. A third decidual vein, smaller than either of the preceding, dips into a different interlobular space, and, after a course of a quarter of an inch, divides into two smaller veins.

Of the decidual arteries, those which open upon the lobules of the placenta make a sudden turn below the uterine layer of the decidua, and terminate there, forming the short curling arteries of Hunter. The interlobular decidual arteries descend

nearly vertically towards the fœtal surface of the placenta. One is seen to reach that surface, accompanying an interlobular decidual vein, described above. Another, larger than the preceding, passes, for the length of half an inch only, into an interlobular space.

This preparation, therefore, distinctly establishes that there exist, formed in the decidua, some terminating on, others extending into, or through the substance of, the placenta, *regular channels;* one set of which is continuous with, and receives blood from the uterine arteries; while the other is continuous with, and returns blood to the uterine veins.

The manner in which the decidual vessels terminate, is best seen in those decidual arteries and veins which enter the substance of the placenta, but do not extend to its fœtal surface. Each of the vessels of this class, that was examined, divides into two branches. These branches, after a short straight course, terminate abruptly. At their abrupt terminations, the tissue of which they are composed appears, at more than one point, to be porous. The lining of the decidual trunks does not appear entirely divested of the same character, but in parts presents smooth and regular openings. This appearance in the decidual trunks is most distinctly seen in a large interlobular decidual vein. Immediately without and around the tissue in which the vascular channels are formed, is the injected and seemingly cellular decidual tissue of the placenta.

The preparation, No. 3535, would indeed leave it in doubt whether the red injection, with which it is coloured, is contained in cells, or in a series of minute decidual tubes, comparable to capillaries. But there are four other preparations in the Hunterian museum, seemingly taken from the same subject with that described, and in which the portions of uterus and placenta are not separated. Three of these, Nos. 3539, 3533, and 3538, and especially the first, certainly display a series of cells filled with black injection from the uterine veins. In one of these, numerous openings into cells from the side of a marginal decidual vein are distinctly to be seen; corresponding with the appearance in the opened decidual vein I in the diagram.

So complete is the evidence to establish that the placenta is a series of cells formed in one part of the decidua, which cells are percolated by the maternal blood that flows into them from the uterine arteries, and finds issue by the uterine veins.

But what again is the distribution of the fœtal vessels in this organ? The principle of their distribution is given in the diagram. M represents a branch of an umbilical artery, ramifying to capillary minuteness between the cells of the placenta. N represents a branch of the umbilical vein, which is formed by the reunion of these capillaries. These capillaries are universally spread through the placenta, and ramify over its cells; as the pulmonary capillaries ramify on the air cells, or as the capillaries of the fœtal cotyledon in the cow ramify on the membrane which supports them. These capillaries are in close contact with cells containing the maternal blood. What difficulty is there in supposing that they may draw from them recrementitious fluid, or imbibe by endosmose what they want for the nourishment of the fœtus, as the pulmonary capillaries imbibe oxygen, or as by a closer analogy the cotyledonous capillaries imbibe aliment?

For a time physiologists sought for a maternal and a fœtal portion of the placenta. Such a distinction does not exist. In the placenta there are essentially three parts: 1. The substratum, or cellular sponge formed of developed decidua. 2. The production of uterine arteries and veins into the placenta, opening into its cells. 3. The universal spread of the umbilical vessels through the entire organ, spreading in capillary reticulation round every cell.

We may finally inquire [if the contrast which I suppose exists between man and other mammalia in the fœto-maternal connection be real], on what principle that distinction is founded. Why should the cotyledonous principle be general in the rest, the placental structure be confined to our own race?

It is by no means unlikely that the periodical secretion of the human uterus, which is, on the one hand, probably connected with the moral and physical constitution of the human female, on the other confers the capability of forming a placenta. The human female, after puberty, is always susceptible of sexual desire; to the permanency of which, unlike the periodic appetites of animals, it is probable that the menstrual secretion contributes. A uterus, with such large secreting powers as the human uterus, may be capable of pouring out decidua, and organizing part of it into a placenta; while the uteri of animals, habituated to no secretion, may on that account be capable of nothing more than increased capillary vascularity.

It has been conjectured by some, that the fœtus is capable of a sort of digestion.

M. Magendie remarks, that the stomach of the fœtus has been found to contain mucus which was opaque and greyish towards the pylorus, as if converted into chyme; and the green matter termed meconium, which is found in the great intestines, has the appearance of being the refuse of a kind of digestion.

In a paper by Dr. Robert Lee, in the Philosophical Transactions for 1829, some interesting observations are made upon this subject.

Dr. Lee observes, that the stomach of the fœtus is usually distended with a semi-transparent, ropy, mucous, and occasionally acescent fluid, without any sensible admixture of albuminous or other nutritious matter. But that in the duodenum and part of the remaining portion of the small intestines there is uniformly present, adhering closely to the mucous membrane, a semi-fluid matter, found on examination to possess properties decidedly of an albuminous character, and to have an orange or pink colour. This matter Dr. R. Lee has always found in greatest abundance around the papillary projection, through which the common duct of the liver opens into the duodenum.

In the lower half of the small intestines the quantity of this albuminous matter is considerably less, and near the colon it almost entirely disappears. The colour also of the contents of this lower portion of the small intestines is different from that noticed in the contents of the duodenum, being of a greenish tint, and assuming more and more of the character of meconium as the distance from the colon diminishes.

The quality of the contents of the jejunum in the fœtus was ascertained to be albuminous by Dr. Prout. Dr. R. Lee conjectures, with great plausibility, that this product is a secretion of the liver.

Of the freedom of communication between the blood of the fœtus and that of the mother, M. Magendie gives this remarkable illustration. He introduced camphor into the veins of a pregnant bitch, and he found that in a quarter of an hour the blood of the fœtus had acquired distinctly the odour of camphor. M. Magendie mentions another curious circumstance. The poisons which rapidly act upon the brain and spinal marrow (such as strychnia) when introduced into the serous cavities or

cellular membrane of adult animals, are harmless when introduced into wounds in unborn animals.

The uterus grows with its enlarging contents, so as constantly to preserve about the same thickness: it is always more than sufficiently capacious, so as to be plastic, not tense.

About the fifth month it rises out of the pelvis, and rests against the front of the abdomen; as it enlarges, the distinction between the body and cervix is lost: the os tincæ is flattened, and forms only a small rugous hole not readily discernible; it is closed by a tough glutinous matter which is fixed in the irregularities of the surface.

The fibres of the uterus exhibit something like a definite disposition as pregnancy advances: viewed from within they are seen to be arranged concentrically round the orifices of the Fallopian tubes. The cervix has not such regular or large fasciculi as the rest of the uterus: when the internal stratum is removed, the fibres of the next layer, which are firmer and tougher than the innermost, seem to have no regular order.

The ordinary period of utero-gestation is forty weeks. But labour frequently takes place before this term is accomplished. A child often lives that is born at eight months, or seven months, or yet earlier. Labour is most likely to occur at the usual expiration of forty weeks; and within that time the probability of its occurrence is directly as the age of the embryo. Premature labour is brought on by any cause which disturbs the system; by fatigue, exposure to excessive heat or cold, anxiety of mind, and the like. But may not labour take place within the forty weeks, and yet not be premature? And, on the other hand, may not the time of gestation be extended over this period?

I cannot quote any better authority upon this subject than that of Dr. Merriman, from a paper by whom, in the Medico-Chirurgical Transactions, vol. xiii, I take the following table: it gives an account of the births of 114 children, calculated from, but not including, the day on which the catamenia were last distinguishable. Dr. Merriman states, that he can fully vouch for its accuracy. He adds, that it seems fair to infer from it, that conception is effected soon after the catamenial period has intermitted, more commonly than immediately before the recurrence of that discharge.

TABLE.

At 255 days	1	
256	1	
259	1	
	3	in the 37th week.
At 262	2	
263	2	
264	4	
265	1	
266	4	
	13	in the 38th week.
At 267	1	
268	1	
269	4	
270	1	
271	2	
272	2	
273	3	
	14	in the 39th week.
At 274	4	
275	2	
276	4	
277	8	
278	3	
279	3	
280	9	
	33	in the 40th week.
At 281	5	
282	2	
283	6	
284	1	
285	4	
286	3	
287	1	
	22	in the 41st week.

At 288 days	5	
289	2	
290	2	
292	4	
293	2	
	15	in the 42d week.
At 295	1	
296	2	
297	2	
298	4	
301	1	
	10	in the 43d week.
At 303	1	
305	1	
306	2	
	4	in the 44th week.

Labour, or the process of delivery, is preceded for two or three days by a mucous discharge from the vagina, and by slight pains about the abdomen and loins. The external parts swell and become relaxed, and even the ligaments of the pelvis lose their tenseness.

The pains of labour commence with and consist in a powerful contraction of the uterus, accompanied with contraction of the abdominal muscles and diaphragm: they are repeated at intervals of half or a quarter of an hour. Impelled by this pressure, the membranes project at and dilate the os tincæ: they burst; the liquor amnii escapes, and at the next pain the pressure of the uterus falls directly upon the fœtus. The head of the fœtus gradually descends, urged on by succeeding spasms, the occiput foremost, the long axis of the head being disposed obliquely across the lesser basin of the pelvis. The occiput, as the external parts yield, glides off the inclined surface of the ischium, presenting at the orifice of the vulva, and bringing at the same time the long diameter of the shoulders to correspond with the greatest breadth of the pelvis. When the head is disengaged, the trunk readily follows. The umbilical cord is then tied, and divided.

If during delivery the opportunity occurs of feeling the fre-

quency of the fœtal pulse in the umbilical cord, it is found to range under sixty in a minute.

After a short time fresh pains return, when the placenta and membranes are detached and expelled. Labour, in the majority of cases, is completed in from four to six hours. The uterus then very slowly and insensibly contracts, so as to diminish the ample cavity, which has been rendered vacant. At the same time its volume is reduced by absorption. During the return of the womb to its former state, a discharge, at first tinged with blood, afterwards of a whitish colour, termed the lochia, ensues, which lasts for several days.

At the moment after birth the infant dilates its chest, and respiration commences; at the same time the foramen ovale and the ductus arteriosus begin to contract and close. A new mode of existence commences. Yet for some time the infant continues immediately dependent upon the maternal system for its nourishment.

The gland of the mamma, remarkable for the whiteness and firmness of its nodular texture, and for the mode in which it is mixed up with adipose substance, consists of several distinct lobes that are supposed to vary from twelve to twenty in number. From innumerable branches in each of these a single duct is formed, which, without communicating with those adjoining, opens in the sulci upon the surface of the nipple.

The mamma has a close sympathy with the uterus, so that it usually enlarges and becomes tender for two or three days before each period. During the latter months of pregnancy the mamma enlarges, and the areola surrounding the nipple takes a darker shade. Towards the time of labour the breast secretes a serous fluid: the secretion has generally the same appearance for two or three days after labour, but at length takes the well-known character of milk. The secretion of milk naturally continues till the middle of the second year. The milk is observed to be more abundant, thicker, and less acid, when the food of the mother principally consists of animal substances: opposite qualities are noticed in milk produced upon a vegetable diet. No secretion indeed is more readily modified by the ingesta, than that under consideration: medicinal substances taken by the mother impart their properties to the milk, which is thus rendered purgative, as the consequence of a dose of rhubarb or of jalap.

The milk of women differs from that of the cow in these particulars: it contains a much smaller quantity of curd, and rather more sugar of milk: its oil is so intimately combined with its curd that it does not yield butter. The quantity of curd increases in proportion to the time after delivery. Asses milk has a very strong resemblance to human milk *.

The rudiments of mammæ originally exist in both sexes; and it is asserted, and is probably true, that there have been instances, in which the gland has been developed and has secreted milk in the male sex.

* Thomson's Chemistry, vol. iv, p. 502.

CHAPTER XIII.

OF GROWTH AND OF REPARATION.

The uses of the different parts of the frame have been now explained; and the wonderful series of changes has been described, through which from a granular speck the embryo attains fœtal maturity. Where these details end, another branch of physiology begins. The history of the subsequent growth of parts, and of their power of restoration when injured — the progress of the frame from childhood to manhood, from manhood to decay—and the study of the influences which promote or impair its energies—are subjects which have a more practical character, and therefore to physicians and surgeons a stronger interest than even those to which I have already adverted. A few only of these topics will however be treated of in the remaining pages of the present volume. I shall confine myself to describing the mode of growth of the unorganized parts of the frame, and the powers of restoration which exist in vascular parts.

Of the Growth of Teeth.

The rudiment of each tooth is a vascular pulp of the shape of the body of the future tooth, the surface of which that is most remote from the gum adheres to the substance of the jaw, and gives entrance to vessels and nerves: the rest of the pulp is unattached. A double membrane is reflected from the margin of the adherent surface, to form a cyst or capsule over the sides and upper part of the pulp. The outer layer of this membrane is soft, thick, and vascular; the inner layer, which is in contact with the pulp, is thin and semi-transparent; it shows no appearance of vascularity, when the outer layer is most successfully injected. In the cavity surrounding the pulp, a transparent yellowish liquid is found.

The growth of the bony portion of the tooth commences by the deposition of a layer of perfect tooth-bone or ivory upon the cutting edge or grinding surface of a tooth. This little cap of bone is therefore an exact mould of the surface by which it was secreted: its adhesion is very slight to the surface of the pulp, which shrinks to give room for the exsudation of a second layer, that coheres inseparably with that first formed. When the pulp shrinks, it at the same time becomes elongated, but in such a manner that the point where its vessels enter remains fixed, and the crown of the tooth is raised towards the margin of the gum. In proportion as the pulp is elongated, the capsules of bone successively formed one within the other are of greater length, being cast upon a longer mould: in this way the whole bony portion of the tooth is produced, the pulp continually diminishing in thickness, but becoming elongated, till it has reached the exact dimension of the future cavity of the tooth. The pulp then ceases to secrete, and wastes to the condition of a vascular membrane, on which however the sensibility and vitality of the tooth which it lines depend.

The preceding circumstances may be verified by examining human teeth at different stages of their formation, and by making sections of the teeth of an animal,—a growing pig for instance,—with the food of which madder has been mixed and discontinued during alternate periods of two or three weeks. In the latter instance the bone of the tooth displays alternate layers of red and white, and the innermost layer is always the longest.

During the elongation of the pulp, the capsule undergoes no change except in place; it rises with the crown of the tooth, to the neck of which it adheres. The enamel is not formed till some time after the bone, and invests that surface only of the tooth which is contained within the capsule.

Some animals have teeth, the pulp of which never shrinks, but continually adds to the length of the tooth: this is the case with the incisors of rodentia, and with the tusks of the elephant. The addition continually making to the roots of the incisors of rodentia is calculated to replace exactly the substance lost by attrition: these teeth are constantly rising in a curve towards each other, and are kept serviceable by the dis-

position of the enamel upon their convex surface alone, which thus always presents a hard and keen edge.

After the division of the fifth nerve in the cranial cavity of a rabbit, I removed the crown of the incisor tooth in the upper jaw of the same side, and compared the time it took to grow to the level of its fellow, with the result of a similar experiment upon a rabbit, in which the fifth nerve had not been divided. The tooth grew rather faster in the former than in the latter instance.

The rudiments of the teeth in the embryo are at first contained in a shallow groove in either jaw with thin partitions between them: they adhere more strictly to the gum than to the base of the socket. In an embryo of four months, twelve little sacs are observed in each jaw, being the rudiments of all the temporary teeth and of the anterior permanent grinders.

The shallow grooves, in which these pulps are first lodged, gradually rise and form alveolar processes: they arch over the pulps of the teeth, leaving, however, an opening towards the gum.

The rudiments of the earliest formed teeth of the second set are at first contained in the same sockets as the temporary teeth, but at the period of birth they are found in separate cells behind and without the cells or sockets of the corresponding temporary teeth. The cells of the second set again are not closed above, but have a narrow channel leading towards the gum, which contains a funnel-like process of the sac, that adheres to the neck of the corresponding temporary tooth.

In an embryo about the eighth month, the pulps of the permanent incisors and cuspidati are found. It is not till after birth that the rudiments of the remaining adult teeth make their appearance, in what order is not precisely known.

The twenty temporary or milk teeth begin to appear on an average about the sixth month. They generally cut the gum in the following succession: the middle incisors of the lower jaw, the middle incisors of the upper, the lateral incisors of the lower jaw, the lateral incisors of the upper,—at intervals of three, four, or five weeks: about the twelfth or fourteenth month, the anterior or small grinders of the under jaw appear, and frequently about the same time those of the upper: about

the sixteenth or twentieth month, the cuspidati appear, first in the lower jaw; and between the twentieth and thirtieth month, the posterior or large grinders appear in the same order.

Before the teeth appear, the gums have a raised firm edge. To make way for the teeth, the upper vaulted part of the alveolar processes and of the gums is absorbed. During this process indisposition frequently supervenes, which may be allayed by cutting down to the tooth at the part where the gum appears slightly swollen: the division should be made anteriorly to the middle of the gum: if the incision be made upon the back part of the gum, it may open the socket of a tooth belonging to the second set, and spoil it.

The thirty-two permanent teeth begin to appear between the sixth and seventh year:—at this time the term of life of the milk teeth has expired; the gums and alveoli no longer adhere to them: they become loosened, and on dropping out, some degree of absorption is generally found to have taken place near the end of the fang. The shedding of the milk teeth does not essentially depend upon the forwardness of the second set: frequently the milk teeth fall out some time before the permanent teeth appear; or the permanent teeth rise, while the milk teeth continue firmly attached, and require extraction to give place to the second set.

The permanent teeth appear in the following order: first, the middle incisors of the lower jaw; soon after, the middle incisors of the upper: then the outer incisors of the lower jaw, and at the same time the permanent anterior grinders: then the lateral incisors of the upper jaw, after some interval. The anterior bicuspides appear about the ninth year, the posterior about the tenth or eleventh: the cuspidati and middle grinders about the twelfth or fourteenth, and finally the last grinders between the ages of sixteen and twenty-five.

Teeth, though not sensibly vascular, have some kind of life. A tooth taken from the head of a living person and immediately fixed in a living part, in the comb of a cock for instance, or in a socket from which another tooth has been drawn, adheres to the raw surface with which it is placed in contact, and becomes permanently attached to it. If the same experiment be tried with a tooth that has been some time removed from the living socket, it fails; the tooth is dead, and contracts no adhesion with a living surface.

The alveolar processes are formed with the teeth: in proportion as the teeth of the infant make their appearance, the branch of the lower jaw lengthens to give them room. When in old age the second set of teeth drops out, the alveolar processes are absorbed; but the same active care is not then shown as during infancy in accommodating the neighbouring parts to this alteration: no ridge of thicker membrane forms upon the edge of the gum to take the place and office of teeth: and no adequate shortening occurs in the branches of the jaw, to allow the gums to meet in exact apposition, and to prevent the characteristic projection of the chin.

Of the unorganized Integuments.

The unorganized integuments, the hair, the nails, the epidermis, are formed of the same chemical elements, which in animals assume the appearance of hoofs, horns, claws, and feathers: the element of which they consist exsudes in a soft state upon vascular surfaces, and quickly hardens by exposure. Of these substances hair and feathers grow upon pulps situated below the skin, the rest are secreted from the cutis.

The cuticle in human beings appears an uniform elastic membrane, the thickness of which is increased in proportion to the pressure made upon it. No definite structure till lately has been attached to it: if on the one hand when forming warts, and on some other occasions, it splits into fibres vertical to the surface, in other instances the cuticle desquamates in layers parallel to the surface, and its texture seems laminated. But the recent researches of M. Breschet have satisfied him, that the general structural disposition of the human cuticle is in laminæ parallel to the surface of the chorion; and that it contains two orders of tubes pervading it: one a spiral, continuous with the spiral tube that penetrates the cutis from the gland that secretes the perspiration: the other arborescent in disposition, the trunk toward the chorion, and supposed by M. Breschet to belong to the absorbent system.

On examining parts in animals, with which the cuticle is continuous, horns for instance, and hoofs, two types of structure are apparent. Horn distinctly consists of fibres, of which the greater part are inclined at an acute angle to the surface on which they grow: the fibres of the tip alone are vertical or nearly so. This structure is apparent on making sections of

variegated horns, and upon peeling horns, that have been softened by maceration in diluted liquor ammoniæ, into strips. Hoof on the other hand has a porous tubular structure. The surface from which it is formed gives off innumerable long and slender villi, that descend in a vertical direction through the hoof towards its under surface, which they nearly reach. The delicate tubes, which render the substance of hoof porous, are the spaces occupied by these villi.

It may be remarked, that the hoof is a part sustaining a tolerably constant and equable pressure: horn on the other hand is only occasionally employed, and that in violent efforts. Now there are various instances in animals, in which the cuticle naturally has a thickness of several lines, and shows a definite structure. In some of these instances again, the pressure which the cuticle sustains is constant, in others occasional only:—it is singular, that in the former case cuticle is found to resemble hoof in structure, in the latter, horn. The cuticle of the whale is porous, and to the minutest points resembles the soft inferior and internal part of a horse's hoof. The cuticle of the ostrich's gizzard on the contrary is distinctly fibrous.

In the epidermis of the ostrich's gizzard the fibres are vertical to the surface; in a cow's horn, the fibres at the tip are vertical, at the sides oblique:—in each instance one principle is held in view; the fibres are so disposed as to be vertical to the pressure or attrition to which they are likely to be exposed. The distinction which I have pointed out between the structure of hoof and horn requires however some qualification. The tubular structure of hoof is in effect fibrous, and even has a fibrous appearance when a section is made through it parallel to the villi. The horn of the rhinoceros again, though its external superficies peels into fibres, yet presents at its base innumerable fine apertures of pores, which it is to be presumed contain in the recent state delicate villi. It is probable that the villous structure, when added to the natural fibrous character of the unorganized integuments, is for the purpose of strengthening their adhesion to the cutis, and preventing cracking.

The nails are formed of an homogeneous substance of the same nature with horn. The apparatus determining their growth and direction is very elaborate. The surface which secretes the nail is of the breadth of the nail, and from a

quarter to a third of an inch in length; its termination is marked by the curved line seen upon the nail, near its point of emerging. That the nail grows from that surface only, which is on the side of this line, remote from the end of the digit, admits of being proved by anatomy, as well as by experiment. For, if a longitudinal section is made of the third phalanx of a finger, with the nail *in situ*, it will be seen that the nail had acquired its full thickness by the time it had reached this line: the nail grows from the surface above and behind this line, being projected from it at an angle so acute, as to move forwards, parallel and adherent to the cutis beyond. There are, however, two other provisions, the one for the adhesion of the nail, the other for its protection when first formed. The surface of cutis on which the nail is slowly propelled towards the end of the digit, is channelled by longitudinal grooves: these grooves are filled by corresponding ridges from the inner surface of the nail; and these ridges are added by a growth, which ensues after the nail is otherwise perfected, and beyond the semicircular margin already referred to.

The provision for the protection of the nail at its formation, is found in a thin fold of skin, which overlaps the organ that secretes the nail, reaching nearly as far as the semicircular line which terminates the former. The office of this fold of skin is not, however, completed by thus covering the soft and tender nail when forming: there is likewise secreted from it a layer of a peculiar epidermis, which rises with the new nail, and unless pruned in cleaning the nail, is carried with it towards the end of the digit. A corresponding growth of cuticle is formed at the bases of horns and hoofs.

The hair, resembling the nails in chemical composition, has a different origin: it is not formed by the cutis, but grows upon little glands, the seat of which, in human beings, is immediately within the cutis, which the hairs perforate through canals lined with epidermis.

The nature of the organ which secretes the hair is often imperfectly understood. It is not uncommon, for example, to speak of the bulb of a hair: now there is but one kind of hair, and that in certain animals only, where a bulb is met with. This hair is what forms the whiskers of animals. Each whisker, at its root, is contained in a strong oval case, of a thin cartilaginous matter, between which and the hair a gelatinous

cellular texture is found. The bulb is perforated at both extremities; at one to let the hair out; at the other to admit the vessels and nerves on which the hair depends for its growth and sensibility. The eye-lashes, which most nearly approach the hair of the whisker, have not bulbs, nor has the hair of the axilla or pubes. The bulbs of the whiskers are intended in part, perhaps, for the protection of the secreting organ of these great hairs, but principally to give purchase to the muscles of the lips upon them, through which they admit of being moved in various senses. Animals, it seems, use their whiskers as an organ of sense. In a seal, of the weight of a middle-sized dog, I found each hair of the whisker supplied by a branch of the fifth, as large as one of the lateral digital nerves.

Hair is considered of two kinds, crinal and pilar: crinal being that upon the head, pilar the stronger hair of the eye-brows, eye-lashes, and on the body. The pilar hair differs from the crinal in being coarser only. The pilar hair presents differences in the rapidity and extent and period of growth in different parts.

The secreting organ, common to all hair, is a conical vascular substance, like the pulp of a tooth; and properly shonld be called the pulp of the hair. In the whisker of the lion, it is of the shape of a pastille. It is found contained within the base of the hair, which is hollow to hold it; or which rather is necessarily hollow, because it is formed upon this pulp, from which the substance of the hair is perpetually secreted, that last exuded softer than the rest, like new-formed nail, but like the new-formed nail, pushing on that previously formed.

A hair is a compound substance, consisting, like a quill, of an exterior denser horny matter, and of an internal, lighter, more spongy tissue.

The vitality of hair is a very curious question. It is uncertain whether the vessels of the pulp are or are not in the natural state continued into the hair, so as to extend through its substance in villi beyond the level of the skin. In well injected pulps of the quills of the porcupine, vascular lines seem to stretch into the structure almost indefinitely, like the vascular villi which pervade two-thirds of the hoof of the horse. If it is true that in the plica polonica the hair sometimes bleeds, the phenomenon is more explicable by supposing an increased action and extension of a structure, the rudiments of which are traceable in health. Some absorbing power, at all events,

in health, must penetrate the hair. It is perfectly attested by Bichat and others, that the hair has lost its colour in the course of twenty-four hours from the influence of depressing mental emotions.

A very remarkable case was not long ago submitted to me, in which a young lady had suddenly lost her hair, which, up to that time, was fine and plentiful. Without any assignable cause, the hair broke off at a quarter of an inch from the head, and fell off in large locks; this singular process has since been repeated every three or four weeks: the hair grows in the intermediate period; then breaks off, leaving the head with the appearance of having been cut close with scissors. Two suppositions are requisite to explain this phenomenon. First, a momentary interruption of growth, rendering the hair almost discontinuous, where it afterwards breaks: secondly, a cause determining the complete discontinuity. I suppose that now the two causes occur simultaneously and are produced by one influence. The young lady has suffered severe pains in the head.

There are other tubes leading through the skin, which give passage to a different element, used like the hair, however, for the protection of the skin. This matter, of an oleaginous quality, exudes upon and forms a natural unguent for the skin. The secreting organ is probably nothing but a tube; it is best seen in the Meibomean glands, which line the tarsi. I may take this opportunity of introducing some notice of the fat, or adipose tissue, in contact with the sub-cutaneous layer of which the pulps of the human hair and the termination of the sebaceous glands are immediately situated.

Fat is an animal oil, contained in minute spherical cells, which are disposed between the skin and cellular tissue in many parts of the body, in the interstices of the muscles, at particular points about the kidney, in the meso-colon and mesentery, and in the appendices epiploicæ, beneath the true pericardium, and sometimes beneath the pleura.

Its accumulation may be viewed as affording a vent for the superfluous hydrogen of the frame. Its re-absorption often proves in illness an important source of nourishment.

There are some persons who have a natural tendency to obesity, and in whom the most guarded abstemiousness will hardly repress it. The most remarkable instance of this kind on record was Daniel Lambert, whose weight was seven hundred and

thirty-nine pounds. He died at the age of forty. When he stood upright, the folds of fat upon his legs almost entirely covered his feet: he was sallow and unhealthy, with a thickly-furred tongue, as I remember, when I saw him.

A Frenchman, named Seurat, who was shown in London a few years ago, with the soubriquet of the "living skeleton," exhibited the opposite extreme. An American, named Calvin Edson, shown more lately, was also extraordinarily emaciated and weighed but fifty-eight pounds. They had no apparent disease. The Frenchman was about thirty years old, and had wasted from infancy: the American about forty, and had wasted for sixteen years. A French penny roll, and a little *vin du pays*, was the Frenchman's daily food in France; and in England a little meat, amounting, with a reduced portion of bread, to three ounces per diem.

II. *Of Restorative Processes.*

When a tooth is broken across, or a hair divided, the part detached has no means of becoming reunited. These are textures which are not vascular, and which once formed undergo no further change, being excluded from nutrition; when worn out, they are replaced, not renovated. Parts on the other hand which are vascular, and which some inward change during their healthiest and strongest condition is perpetually going on, when injured exhibit determinate powers of self-reparation. These restorative powers are, ADHESION, INFLAMMATION, UNIONBY CALLUS.

1. *Of Adhesion.*

If the edges or surfaces of a clean wound of the integuments, extending or not to the cellular tissue, muscles, the mucous or serous membranes, or of the cornea, are laid in apposition, they become first glued together, and afterwards cohere by restored vascular continuity.

The medium of union is either a thin film of blood, or of fibrin.

The former is used in trifling incisions through the skin, which happen to be closed immediately.

In all other cases the bond of union is fibrin. From the vessels of the cut surface which have ceased to bleed, liquid fibrin exsudes, which glazes the surface like a layer of plastic

glue, and when those surfaces are laid in apposition, coagulating firmly unites them. The layer of fibrin is extremely thin, probably not exceeding one-hundredth of an inch.

The surfaces of a wound are fit for this process as soon as hemorrhage has ceased. In a shallow wound, like that in the operation for hare lip, five or ten minutes are commonly sufficient. In a deep wound (for example after an amputation) it is best to wait four or five hours, the parts being for that period lightly approximated. At the expiration of four or five hours the wound requires to be opened, the coagula which have formed at different parts, from the continuing or renewed hemorrhage of small vessels, have to be removed, and the glazed surfaces have to be applied to each other, and maintained in contact by moderate pressure.

The period is not known, at which it is too late to produce union by adhesion: under common circumstances, it probably extends to twelve hours, or longer: if the habit is inflammatory, the period must be shorter; if the circulation is depressed by hemorrhage and cold, the period must be longer.

The junction, thus mechanically commenced, is converted into organized union by vessels extending through the layer of fibrin. It is supposed, upon analogy, that this process begins within twenty-four hours. Peritoneal lymph, Sir Everard Home found in one instance had become organized in that period. In general, either organized union is completed, or the process has entirely failed in forty-eight hours. This is seen in cases of staphyloraphe, or of artificial reparation of congenital fissure of the palate. In persons of an asthenic habit the process is slower. I operated for hare-lip in a young lady, upon whom the same operation had been three times before performed by other surgeons, and had failed. I retained the pins in the lip for five days: on removing them, I observed that the bond of union was not organized, and like unset glue began at the corner to give way. Not allowing the parts to separate, I secured their continued apposition by pieces of sticking plaister: organized union followed.

The conditions which promote union by adhesion are coolness of the part, rest, the maintenance of contact by moderate pressure and support. The period, for which these conditions are to be maintained, varies with the extent of the wound. The film of union has no great tenacity. However perfect the

union at the expiration of three or four days, a very little force will separate it. In a large wound the rapidity of the organizing process is different at different parts.

Union by adhesion is liable to fail, first, from interrupted contact through exsudation of blood ; secondly, from motion of the part displacing the parts apposed ; thirdly, from the means maintaining approximation giving way, for example, bandages stretching, pinholes ulcerating ; fourthly, from the pressure employed being so great as to produce mortification or inflammation ; fifthly, from inflammation ensuing through the habit being inflammatory, or the part being kept at too high a temperature.

Union by adhesion will take place of strange surfaces to each other, as of one leg to the opposite : and even when a part has been temporarily separated from the body, and has undergone suspension of circulation and life. A tooth, the spur of a cock, Mr. Hunter thus transplanted into the comb of the animal, and they adhered and lived.

2. *Of Inflammation.*

When union by adhesion has failed, union through inflammation may take place.

Inflammation must be viewed as a mixed process. It cannot be considered in the present state of our knowledge as purely restorative. In a great number of instances every stage of inflammation appears injurious to the part and to the system. Nevertheless we cannot positively affirm that in any case it may not be an effort, although often a fruitless one, towards relief. Certainly in the reparation of wounds it bears this character; and in all cases, whether practically restorative or destructive, its features and essence are the same. They are the following.

An external part inflamed is hotter than before, redder, swollen, and painful.

The heat does not rise above that of the blood. Mr. Hunter, when operating in a case of hydrocele, ascertained the temperature of the tunica vaginalis to be 92° : on the following day, when inflammation had supervened, the temperature of the wound was 98½°.

The redness results from the afflux of blood. This is de-

monstrable universally by artificial injections after death, and may be seen upon the inflamed conjunctiva during life.

The swelling results partly from the increased quantity of blood, partly from interstitial effusion.

The pain, whether numb or acute, whether aching or burning, or tingling, or shooting, must be attributed to the altered circulation in the nerves of the part.

In inflammation there are two changes in the state of the vessels, one common to the arteries and capillaries, the other confined to the capillaries.

a. More blood is sent to an inflamed part, than to a part not inflamed. Mr. Lawrence ascertained this to be the fact by bleeding patients with inflammation of one arm, simultaneously in both; about three times as much blood flowed from the vein of the inflamed arm, as from the vein of the uninflamed limb. We likewise see the veins of an inflamed limb to be full of blood, and feel the artery to be large and full.

The flow of the blood in increased quantity into the limb I believe not to be inflammation, but an accessory only in the process. I believe it to be an event analogous to the increased flow of blood to the gravid uterus and to the secreting mamma, and produced in the same way. I suppose, agreeably with the theory explained at page 53, that it takes place through the arteries in the part becoming relaxed, whereby they yield a freer passage of blood into the part than before,—a freer passage than the arteries of other parts of the same body that are not relaxed allow of. The relaxed arteries make less opposition than unrelaxed arteries to the impulse of the blood, and yielding become larger tubes, and so contain and carry into the part a disproportionate quantity of blood.

b. The specifically inflammatory character or condition of the vessels is the following. Its seat is the capillaries. When viewed in a microscope [as may be contrived with transparent membranes of living animals], the capillaries, on inflammation being excited, are seen to dilate, and the blood is seen to move more slowly in them: in the centres, where the inflammation is highest, its motion entirely stops, and the distinction of coloured particles and of the liquid in which they float is lost; the blood has coagulated. So are there three zones visible in such an observation: in the central space the blood has stopped in

enlarged capillaries, in the surrounding region the blood is moving slowly in enlarged capillaries, in the zone around the blood is moving with its accustomed rapidity in unenlarged capillaries.

How are these phenomena to be accounted for,—the dilatation of the capillaries, and the clotting of the blood? The former I account for on the same supposition which accounts for the dilatation of the larger arteries in the part. The latter I think is of the same class of phenomena as the following. If a vessel is irritated,—if, for instance, a caustic issue is made over a vein,—or if the lining membrane of the heart is scratched with a pointed instrument,—the blood flowing in the vein or over the serous surface, clots upon and adheres to that surface.

That irritation may have different sources in ordinary inflammations. In one case it is mechanical lesion, in another an impression through the nerves, in another the withholding nervous influence; but whatever its source, it acts *thus*: the vessels become relaxed; and thickening or coagulation of the blood flowing through them takes place in the capillaries the most highly irritated.

It is interesting to consider further the relation of the state of the capillaries in the inflamed part to the state of the arteries leading to them. The latter are relaxed through the extension of the irritation to them. They allow the blood to flow in increased quantity into the inflamed region; but this does not lead to an increased quantity of circulation in the actual seat of the inflammation. *There* there is more blood indeed, for the vessels are dilated; but that blood is either stagnant, or moving slowly.

The process which has been described has in it nothing directly restorative: on the contrary, it interferes with that process. When it supervenes in a wound, the layer of uniting lymph, previously there, is never organized; but is washed away by an exudation of serum.

But first, in the theory of inflammation it is to be understood that the process may end by resolution; that the changes which have been described may go as they came, without leaving any consequence. The blood is seen in such cases [when artificially produced for the purpose] to move more quickly where it recently moved slowly; to move again where it was recently stationary; finally, to regain in each part its normal velocity,

the capillaries at the same time gradually shrinking or contracting to the size of health.

And secondly, in the opposite extreme, the process may be destructive. If the irritation has been extensive and violent, the blood clots in all the capillaries of the part; the circulation is at an end; life is suspended in the part irretrievably, or *mortification* takes place.

Intermediately between these extremes occur the phenomena, through which inflammation is restorative; but all the intermediate phenomena are not of this nature.

Inflammation may be followed by effusion of serum, effusion of lymph, effusion of blood, effusion of pus, ulceration, granulation, cicatrization.

1. *Effusion of serum.*—Serum is the earliest inflammatory product: it exudes upon surfaces, and into the texture of organs: it is the cause of some of the tumefaction and of the brittleness of parts in the first stage of inflammation. What is the rationale of this phenomenon? The blood *is obstructed* in some of the capillaries of the inflamed region; its thinner part is therefore mechanically forced through the coats of the vessels. The same effect invariably results from the cause assigned, whether the obstruction be inflammatory or not. When the axillary vein is obstructed by the pressure of enlarged glands, the arm becomes œdematous. When the upper cava is compressed by a tumour, the face, throat, and arms, become anasarcous. When the cavity of the inferior cava is obliterated, the legs swell. When the hepatic circulation is obstructed, ascites follows.

2. *Effusion of lymph.*—Lymph, or liquid fibrin, exudes upon inflamed surfaces, and into the texture of inflamed organs. To reach its source, the reader must be made acquainted with the conditions of inflamed blood. Their study reflects additional light upon some points already stated.

Inflammatory blood exhibits three degrees or stages.

a. In the lowest degree, it forms a firmer clot than usual; evincing a *disposition to clot*, which no doubt contributes to the clotting already spoken of in the capillaries in the centre of an inflammation. The upper part of this firmer clot has the greatest tendency to contract; whence it follows, that it is more or less excavated or cupped.

b. In the second degree, there separates from the blood

before it clots a small quantity of liquid fibrin, which floats on its surface: clotting when the blood clots, this fibrin forms a thin filmy layer, semi-transparent, a *size* as it is called.

c. In the third stage, liquid fibrin separates in larger quantity; and when it clots, forms a straw-coloured layer a third of an inch or more in thickness upon the upper surface of the red coagulum with which it is continuous. This is called a *buffy coat*. The contraction of the entire clot is sometimes forcible, but does not nearly equal that of the upper layer. The blood is deeply cupped as well as buffed.

Thus it appears, that, in inflamed blood, liquid fibrin has a disposition to separate from the rest. But the lymph of inflammation is liquid fibrin; and Hewson proved that the fibrin of inflamed blood is more attenuated than that of healthy blood. No wonder that it strains out from the same cause with the serum.

A coagulable inflammatory effusion presents two degrees. In ordinary pleuritic effusion, the liquid is largely diluted with serum; the quantity of fibrin is small; the layer which coagulates thin. On the other hand, upon the iris, upon healthy ulcers, upon a fresh wound, in the peritoneum, in the most restorative inflammation, the liquid which exudes is pure fibrin, and entirely coagulates.

3. *Effusion of blood.*—In inflamed parts more or less blood is continually effused, mixed with the other products. Is it surprising that this should happen, when the serum and the fibrin are profusely escaping?

4. *Effusion of pus.*—Pus is a viscid straw-coloured fluid, of the specific gravity of 1050: it coagulates when raised to the temperature of 112°, or when mixed with muriate of ammonia. Its colour depends upon innumerable particles suspended in it. What is the nature and source of this fluid?

I have ascertained that the particles of pus bear the following relation to those of the blood. They are exactly of the same shape; that is to say, they resemble in form silk-worms' eggs, being circular flattened discs with rounded edges, having a shallow circular depression on each flat surface. They were previously known to be circular, and to be larger than blood-particles. Measuring them, I found their diameter to be $\frac{1}{2000}$ of an inch; while, in the same micrometer, the particles of blood appear to be $\frac{1}{3000}$ of an inch in diameter, agreeably with Dr. Hodgkin's and Mr. Lister's, and my own previous observations.

Particles of pus are therefore without doubt particles fo

blood slightly changed. Long before I ascertained their relation in form to the blood particles, Gendrin had seen the blood particles moving in the vessels of an inflamed transparent membrane, as they approached the surface of an ulcer, discharge their colour, and become pus particles.

Pus thus is formed in the vessels of an inflamed part from the blood: its transudation is not surprising, when serum, lymph, and blood, have been already shown to escape.

5. *Ulceration.*—Ulceration is effected by molecular absorption: but all absorption is not ulceration. Ulceration is the absorption of a part, leaving a new and free surface. It is probable that ulceration never takes place without inflammation: but ulceration may take place without granulation, or the formation of pus. This is shown in ulcerating articular cartilage. Ulceration is so far restorative, that it is the means by which a dead part is got rid of antecedently to the reparation of a wound. By ulceration, the living part adjoining the dead is carried away; whereupon the dead part becomes detached.

6. *Granulation.*—It is now that the restorative agency of inflammation shows itself. Granulations are lymph that has exuded upon an ulcerated surface, and become organized: but that lymph is a product of inflammation. Granulations are a soft, tender, vascular layer of lymph, with a surface not even, but covered with small irregular points. The granulating surface furnishes two secretions, both inflammatory; the one, pus, with which it is lubricated and protected; the other, liquid fibrin, which, coagulating, is organized from the surface it adheres to, and forms an additional layer of granulations.

7. *Cicatrization.*—This is the conversion of granulations into a substitute for skin. The process commonly takes place at the edges alone of the granulated surface; sometimes at the middle as well. The granulations change into a soft moist substance, of a pink colour at first, with a dry surface. This is cicatrix; it gradually thickens, and becomes white. The day that a portion of cicatrix is completed, it is insensible: about a fortnight after, it feels if pricked.

3. *Of union by callus.*

When tendons or nerves, cartilages or bones, are divided or broken across, the process of their reunion, instead of resembling the adhesive process, has more in common with the growth of a cicatrix. The injured parts are

repaired through the intervention of a third substance, the product of a change in the neighbouring cellular texture.

If the tendo Achillis is examined in a dog forty-eight hours after division, upon removing the skin, the subjacent cellular membrane that surrounds the tendon appears loaded with coagulable lymph and extravasated blood. Upon making a longitudinal section of the thickened substance, the cut ends of the tendon contained within it are found to be about an inch apart, but connected together by means of coagulated blood and swollen cellular texture.

If the tendo Achillis is examined seven days after division, the ends of the divided tendon are found united by an intervening substance of greater thickness than the tendon itself, that is readily separable from the skin and subjacent parts. Upon a longitudinal section being made, the intervening substance appears of a dark-red colour, firm, and to a certain degree elastic: it coheres, in some parts firmly, in others slightly, with *the cut ends* of the tendon, but strongly and inseparably with *the cellular sheath* of the tendon, which is discoloured for some distance from the wound; so that either end of the tendon admits without much force of being displaced from a socket in the intervening substance.

At seventeen days after division, the intervening substance [or *callus* as it may be termed] is found diminished in thickness, and to be firmer, paler, and inseparably coherent with the cut ends of the tendon, the nature of which it gradually assumes.

The redness which I observed the callus to have, in the early stages of these experiments, is to be considered as accidental. The only mode of dividing the tendon was to cut it. But this involved an external wound; and although that wound healed by adhesion, and allowed the tendon to unite as a ruptured tendon unites, still it necessarily involved effusion of blood, which infiltrated the cellular membrane.

When a nerve is divided, the process by which its ends are joined closely resembles the mode in which tendons unite. Without detailing the appearances on dissection at an earlier period, let me describe the state of the part at the time when the return of its function first manifests itself.

I divided the infra-orbital nerve on one side upon the face of a cat, and removed a minute portion. The skin of the upper

lip immediately lost sensation. The wound, however, readily cicatrized; and by the twentieth day sensation appeared entirely restored. Upon examining the part at this period, the nervous fibrils appeared to be united by a thick knot [or callus] of tough gray semi-transparent substance. On making a longitudinal section of this substance, and of the nervous fibrils which entered it, the extremities of the divided filaments appeared nearly two lines asunder, and firmly coherent with the intervening substance: here and there a whitish fibril seemed to extend further into the connecting medium, but no restoration of continuity by nervous substance between the fibrils was yet observable.

When the portio dura is divided on the face of an animal, it unites in a similar manner; but the nerve does not begin under four weeks to resume the office of transmitting the influence of the will. About this time, the eyelids, which hitherto have been motionless, are observed to be slowly and imperfectly drawn towards each other, whenever the surface of the conjunctiva is touched.

Cruikshank and Haighton observed, that if the pneumogastric nerve is divided, first on one side, and then on the other, with an interval of three weeks between each operation, by the expiration of that time the nerve first divided has united sufficiently to have its function restored, and the division of the second is not necessarily fatal. Magendie indeed denies that this result ensues: *he* found that the division of the second nerve was as fatal at the expiration of several weeks, as if it had been performed at the same time with the division of the first. I have recently repeated the experiment, dividing the second nerve a month after the first: the animal died in three days. On examining the parts, however, I found that the nerve that had been first cut (a small portion, I should mention, had been removed) *had happened not to unite:* the upper portion retained its volume and colour, and ended in a white bulb: the lower portion was shrunk in size, and was greyish or semi-transparent in colour. As it is not possible to doubt the correctness of Cruikshank's and Haighton's experiments, I am inclined to suppose that in the instances in which the experiment did not succeed with Magendie, the failure was owing (as in my own case) to *an accidental want of union* between the extremities of the nerve first divided.

If the cartilage of a rib is examined in a dog forty-eight hours after division, the cut surfaces of the cartilage are not found to have undergone any change: they are held together by a loose capsule formed by the surrounding parts. Towards the seventh day this capsule has assumed a dense elastic texture, and distinctly includes the adjacent cellular membrane and muscular substance. The edges of the cartilage appear rounded off, and a slight exsudation of lymph seems interposed between the disjoined surfaces. On the seventeenth day the appearance is much the same; the intervening substance, which has acquired consistence, is continuous with and appears derived from the capsule or callus. About the twenty-eighth day, the intervening layer of lymph is found adhering to and loosely uniting the opposite cartilaginous surfaces.

The changes which attend the reunion of a broken bone are even more elaborate than those which occur in the preceding instances. The most valuable observations which have been published upon this subject are by M. Dupuytren. The phenomena which are observable during the first month, I had, in concert with Mr. Derwentwater Ratcliffe, ascertained by experiment, without knowing that they had been already described.

If a fractured limb is examined within forty-eight hours after the injury, the periosteum is found to have been stripped irregularly from the broken ends of the bone: the cancelli of the bone and the neighbouring soft parts seem in a state of ecchymosis; the quantity of blood, however, effused from the ruptured vessels is generally inconsiderable. Where it is considerable, the process of restoration is found to be retarded.

On the fourth day a change is found to have supervened; the parts adjacent to the broken ends of the bone have become condensed by infiltration with gelatinous lymph, and form a capsule, which contains the broken extremities. The thickening includes every neighbouring texture: the muscles, tendons, and cellular membrane, for the extent of several lines, seem condensed into one tough elastic mass.

During the next fortnight this capsule becomes of greater firmness: at the same time the special textures which are involved in the injured thickening become extricated from it; the tendons sometimes continuing to occupy distinct grooves in

it. The capsule now changes into cartilage, and is termed the provisional callus.

After the third week ossification commences in the callus. By the expiration of four or five or six weeks the broken ends of the bone are united by an osseous case extending from the one to the other, having its adhesion at some little distance from the fractured edge. The only union between the *extremities* of the bones, that hitherto has taken place, is by organized lymph. It is still soft, but highly vascular.

During the interval between the sixth week and the fifth or sixth month, the process of ossification extends from the capsule to the soft substance which directly unites the broken surfaces. The medium of direct union ossifying is called the *definitive callus.* At the same time the provisional callus shrinks in proportion as the direct union renders its continuance unnecessary. After a few months more, the provisional callus has disappeared, the bone has shrunk to the natural size, and even its cavity is gradually restored.

Thus it appears established upon a very extensive induction, that union of internal parts depends upon changes which take place in the adjacent textures, among which the cellular membrane is probably the most important. This conclusion derives support from, at the same time that it serves to explain, the curious circumstance, that fractures of a bone at a part where it is insulated from the surrounding textures, most rarely unite by bone. In Sir Astley Cooper's Treatise on Dislocations, the fact is proved by reference to a vast body of evidence, that when the neck of the femur is broken within the capsular membrane, bony union does not usually follow.

Of several instances, which I have myself had an opportunity of examining, let me select the following to illustrate this anomaly. A woman about the age of fifty fell with great violence upon the left hip. The limb was not shortened, but was rendered useless: pain and swelling ensued. She was confined to her bed for five months; after which she gradually regained strength in the injured hip, and became enabled to walk with the assistance of a stick. Thirteen months after the accident she died suddenly of apoplexy. Upon examination, the neck of the femur was found to have been broken within the capsular membrane: union had taken place by a layer of

soft but tough substance three lines in thickness, in which, however, not the least trace of earthy matter was discovered. The preparation, with the details of the case, was given to me by my friend Mr. Sweatman: there is an engraving from it in Sir Astley Cooper's work on Dislocations. In a fracture of this description, it is obvious that the broken ends of bone remain enclosed in a synovial cavity, whereby they are cut off from continuity with those parts, the changes in which lead to union in other cases.

When the neck of the femur is broken, and the fracture is half within and half without the capsular membrane, the former part has been found united by ligament, the latter by bone.

When the fracture is entirely within the capsular membrane, and ligamentous union ensues, some growth of bone is occasionally found to have occurred *on the outside of* the capsule,—the commencement doubtless of the process, which has been already described in the ordinary reparation of bone, but which in this case is prevented having any useful effect by the intervention of the synovial membrane.

It must not, however, be denied, that union by bone, in fracture of the neck of the femur within the capsule, is possible. It has been proved that it occasionally takes place: but the process is slow, and follows at a long interval a previous soft or ligamentous union. The possibility of ossification gradually extending across from bone to bone is shown by what happens after loss of part of the cranium. When the skull is fractured, the membrane on either side of it undergoes no change like that which leads to the reparation of other bones: no thickening takes place; no callus is formed; and for several months there is no apparent attempt at restoration. But the edges of the broken bone are observed gradually to become rounded, and after a time to encroach upon the intervening membranous substance, the extent of which in the lapse of months and years becomes less and less, the bones either partially, or, if the fissure be narrow, wholly uniting by a direct extension of ossification from one to the other*.

I may mention, in conclusion, an instance of deficient union

* I have allowed this brief outline of the general process of reparation to remain in the present edition of this book; but the subject more properly belongs to Pathology: and the reader will find it more fully treated in my outlines of that science.

after partial division of a nerve, which is closely parallel to the common case of deficient bony union after fracture of the cervix femoris. An attempt was made to divide the fifth nerve at the side of the pons Varolii in a young cat. The animal immediately lost the sense of feeling in the parts supplied by the first and second divisions of the fifth, and the cornea in a few days became partially opaque: but the iris moved, and the animal saw distinctly with the eye, which had lost the sense of touch. During eighteen months no further change ensued: not the slightest return of feeling was observable in the eye, the nostril, or cheek of the mutilated side. At this period the animal was killed. Upon examination the following appearanees presented themselves. The fifth nerve had not been entirely divided; which accounted for the continuance of sensation in the parts supplied by the third division of that nerve. What remained undivided of the fibrils of the fifth held the severed fibrils nearly in apposition, and at the distance only of a line asunder: *they were united by a thin film,* which seemed a clot of blood, that had nearly lost its colouring matter; the adhesion gave way on slight pressure.

Now a nerve when traversing the cavity of the arachnoïd membrane is in a position analogous to that of the neck of the thigh bone: it is not surrounded by cellular texture; and its restoration when divided is imperfect.

Yet in such a case every other condition favourable to reparation is present: the divided surfaces are nearly in apposition, the supply of blood is not interrupted, and the parts are kept perfectly at rest.

But what, it will be inquired, is the nature of that action, which set on foot in the neighbourhood of the injured parts leads to their restoration?—this effusion of gelatinous lymph, which gradually hardens into an appropriate callus. Is the action inflammatory? I think that it is not. Inflammation is the general attendant of *compound* fractures of bones; the process which it sets up is seen to be materially different from the phenomena which attend the reparation of simple fractures. Suppuration and granulation take place; and the granulations formed in the wound become the callus.

It is true indeed that these granulations are organized lymph, and so is the provisional callus of simple fracture. But there is another phenomenon, which closely borders upon inflammation,

and yet is different, which comes nearest, probably, to the action sought to be explained.

When conception has taken place, the uterus becomes more vascular than before; and its inner surface, when the opportunity occurs of injecting it with size and vermilion, is rendered of the brightest red. But that redness is not inflammation. Nevertheless it is accompanied by one of the products of inflammation. Lymph (which is to form the decidua and placenta) is poured out by the vascular surface. Increased action is then present; and with it, a product identical with one of those of inflammation. Such likewise are probably the elements in the reparation of parts (injured without an external wound) by means of a provisional callus.

CHAPTER XIV.

OF THE VARIETIES OF THE HUMAN SPECIES.

In a system of physiology, however elementary, some account is expected of the diversities which the human race presents in different parts of the globe. To follow this subject in all its bearings, to consider it as illustrating the origin and primary condition, the early habitation, and the distribution, of our species, constitutes one of the most interesting branches of speculative research. Such an inquiry demands a critical study of the traditional history of nations, of their affinities in language and customs, of their resemblance in mental endowments and in physical character, as well as a careful examination of the analogies which the natural history of other living beings presents. The most important questions among those which I have enumerated, the student will find very ably treated in Dr. Prichard's work upon the Physical History of Man: he may likewise consult with advantage the Lectures of Mr. Lawrence; and in the Decades Craniorum of Blumenbach he may examine a part of the original materials upon which that celebrated naturalist of the human species founded his classification of the families of mankind by their physical character.

It is to the last inquiry alone that I shall advert on the present occasion. By extracts from the authorities collected and quoted by Dr. Prichard, I shall attempt to display the most remarkable differences in form and structure that are observed in different nations. They will be found to be such as we may reasonably suppose to have resulted from the influence of accidental causes operating upon one original species or family. Yet had we not additional evidence to that which the physiological study of Man presents, the opposite hypothesis would have been far from untenable; and we might have concluded, that the earth was peopled at different points, with families of human beings of different physical organization, appropriated to the

climates in which they were placed; and that the numerous intermediate shades, which now blend together and combine the whole into one continuous series, have resulted from subsequent intermixtures of branches of the original tribes.

The characteristic differences among mankind are found in the colour of the skin, in the texture of the hair, and in the shape of the cranium and face.

1. The differences of colour among different nations may be ranged under two classes, the melanic and the xanthous.

The melanic variety includes all individuals or races who have black hair, and forms by far the most numerous part of mankind. The hue of the skin varies, from a deep black, which is the hue of some African nations, to a much lighter or more diluted shade. The dusky hue is combined in some nations with a mixture of red, in others with a tinge of yellow. The former are the copper-coloured nations of America and Africa, the latter the olive-coloured races of Asia. In the deepness or intensity of colour, we find every shade or gradation, from the black of the Senegal Negro, or the deep olive and almost jet-black of the Malabars, and some other nations of India, to the light olive of the northern Hindoos. From that we still trace every variety of shade among the Persians and other Asiatics, to the complexion of the swarthy Spaniards, or European brunettes in general.

The xanthous variety includes all those individuals who have light brown, auburn, yellow, or red hair. With hair of these colours is almost always combined a fair complexion, which on exposure to heat acquires not a black or deep brown hue, but more or less of a red tint. This variety, however, passes insensibly into the others: it would be difficult to determine whether some of the individuals belong to it or to the melanic.

The seat of the dark-coloured families of mankind is within or near the tropics; and the circumstances under which the darkest shades are found, and which we are led to view as productive of them, are a more completely savage state, a more immediate vicinity to the equator, and a situation but little raised above the level of the sea.

Under opposite circumstances, the colour of the skin becomes lighter. There is something in the temperately cold regions of Europe and Asia, which especially favours the production of the xanthous variety; it is in these countries that it prevails,

and is in some instances the general character of whole tribes. Either it springs up more frequently in these regions than elsewhere, or when it casually appears, multiplies and is propagated more extensively. It is not uncommon to find it prevailing in high hilly tracts, while in the neighbouring low grounds it gives place to the melanic variety. It has been observed, that the western regions of North America assimilate nearly in climate to the same latitudes in Europe. This remark applies to the country between the Esquimaux to the north, and the neighbourhood of Port Discovery in the forty-eighth degree of latitude to the south. It is extremely interesting to remark, that the inhabitants of these regions, consisting of several distinct races, are as white as the nations of Europe.

It appears that among the races of the darkest colour, the xanthous complexion occasionally manifests itself. Pallas has minutely described a white negress seen by him in London in 1761. She was born of negro parents in Jamaica, and was sixteen years of age. She was of small stature, fair complexion, with ruddy lips and cheeks. The iris was of a brownish grey colour. Her hair, which was quite woolly in texture, was of a light yellow colour, or what the French call "blond." This girl had the negro features strongly marked, and had every appearance of negro descent. Such an occurrence, however, is exceedingly rare; but a deviation not very distantly removed from it is by no means unfrequent. Persons are occasionally born, of every race of mankind, who to the features of that race join a complexion without colour; not pale indeed, but rather a milk white; yet occasionally it has a uniform light tint of the faintest pink. The eye has no black pigment, so that the iris and pupil are of different shades of red: the hair is of a pale yellowish white or cream colour, but sometimes in European people of this description it has a pale gold colour, resembling in texture and glossiness unwrought silk. Persons with this appearance are termed albinoes. Like pied people, they have not occurred in such numbers as to form a large proportion of the inhabitants of particular districts.

2. The hair of the head presents three especial varieties of texture: either, as in the African, it is crisp and woolly, the filaments fine and short, with a peculiar spiral twist, and apparently a roughness of surface, which occasions them to become matted, and in some measure felted into a mass; or it is long,

coarse, and lank, as in the eastern Asiatics; or it is soft and flowing, and inclined to curl, as in the inhabitants of almost the whole of Europe.

3. There are three principal varieties in the form of the skull, which, to borrow the terms employed by Dr. Prichard, may be termed steno-bregmate, meso-bregmate, and platy-bregmate: they are thus characterized.

1. *Of the steno-bregmate cranium.*

The head narrow, compressed at the sides; the forehead very convex, vaulted; the cheek bones projecting *forwards:* the nostrils wide; the fossæ maxillares deeply marked behind the infra-orbital foramen; the jaws lengthened; the alveolar edge narrow, long, and elliptical; the front teeth of the upper jaw turned obliquely forwards; the lower jaw strong and large; the skull in general thick and heavy.

Face narrow, projecting towards the lower part; eyes projecting (à fleur de tête), nose spread and almost confounded with the cheeks: the lips, particularly the upper one, very thick; the jaws prominent, the chin receding.

2. *Of the meso-bregmate cranium.*

The head of the most symmetrical shape, almost round; the forehead of moderate extent; the cheek bones rather narrow without any projection, but having a direction downwards from the malar process of the frontal bone; the alveolar edge well rounded: the front teeth of each jaw placed perpendicularly.

The face of an oval shape, straight; features moderately prominent; forehead arched; nose narrow, slightly arched, or at least with the bridge somewhat convex; cheek bones not at all projecting; mouth small, with the lips slightly turned out, particularly the lower one; chin full and round.

3. *Of the platy-bregmate cranium.*

The head almost square; the cheek bones projecting outwards; the nose flat; the nasal bones and the space between the eyebrows nearly on the same horizontal plane with the cheek bones; the superciliary arches scarcely to be perceived; the nostrils narrow; the alveolar edge in some degree rounded forwards; the chin slightly prominent.

Face broad and flattened, with the parts imperfectly dis-

tinguished; the space between the eyes flat and very broad; nose flat; cheeks projecting, round; narrow and linear aperture of the eyelids extending towards the temples; the internal angle of the eye depressed towards the nose, and the superior eyelid continued at that part into the inferior by a rounded sweep; chin slightly prominent.

The adjoined figures represent instances of the three extreme diversities in the form of the head, in the order in which they have been described. The heads are supposed to be seen from above, in which position the differences from which the terms, steno-bregmate, meso-bregmate, and platy-bregmate are taken, are most observable*.

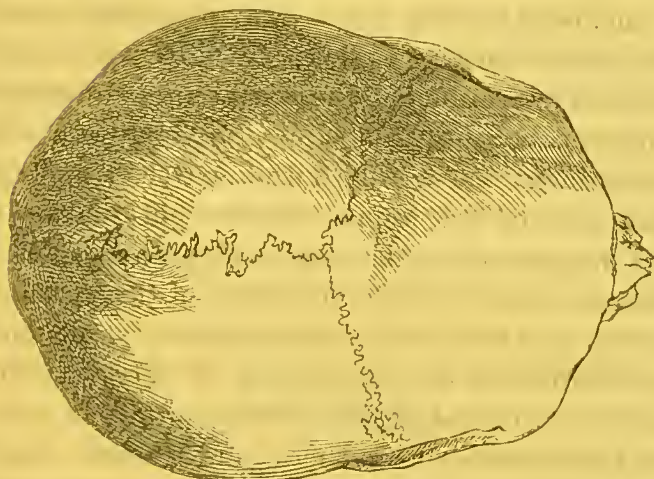
When we now cast our eyes over the great continents of the globe, to see whether the peculiarities in colour and in the shape of the head, which have been described, occur indiscriminately in the same regions, or are preserved apart, giving a characteristic appearance to the inhabitants of different countries, we notice, that individuals may be found in every nation, who, in their form, recede from either extreme, and come near to the mean type of the human family; but that nevertheless in different regions one particular configuration is more especially affected, so as to be characteristic of their inhabitants.

The natives of Africa have steno-bregmate skulls and woolly hair; the inhabitants of Europe and of the western part of Asia, exhibit the meso-bregmate skull, with soft and flowing hair; the inhabitants of northern and eastern Asia and of America, are characterized by the platy-bregmate skull, with coarse and lank hair.

Each of these varieties contain tribes of a dark colour, but the darkest shades belong to the steno-bregmate variety: the fairest to the meso-bregmate: the olive and tawny colour are most prevalent in the platy-bregmate.

The people of the islands in the great Southern Ocean pre-

* There is a singularity which I do not remember to have seen anywhere noticed, that I have observed in one steno-bregmate and in one platy-bregmate skull, both of which were otherwise *extreme* specimens. The coronal suture, instead of being received upon the sphenoïd bone, in each terminated upon an advanced part of the squamous portion of the temporal. What struck me as giving the more interest to this observation is, that I observe in the head of the Oran Otang the coronal suture to terminate as in the meso-bregmate human skull, whereas in the inferior simiæ it ends upon the temporal bone.



sent a physical character more diversified and capricious than that of the continents of the globe; yet its varieties are in great measure referable to the three great classes which have been described; many islands contain two distinct races, one of Indian, the other of Negro conformation. Others again have inhabitants in which we recognize the physical character belonging to the meso-bregmate variety. But the great Southern Ocean is bounded by continents, on the shores of which are spread races of mankind having each of the three primary characters which have been described; it is not therefore surprising that its islands should be promiscuously peopled with races whose diversified characters resemble those of the three continental varieties. It is to be remarked, however, that in the Alfourous, who will be described in connection with the Papuas or modified Ethiopian variety in Polynesia, peculiar points of difference occur, which have led some to consider these as a separate race,—the indigenous family of that region.

Let me now complete the design I have in view, by exhibiting various *sections* of mankind, selected in such a manner as to show the range of variety, or deviation from the three primitive or extreme types, which different races of mankind present.

Of the diversities among the steno-bregmate or Æthiopian variety of mankind.

The instances which I have selected will show how far from generally prevalent among the nations of Africa is the combination of the steno-bregmate skull with a skin of the darkest shade of brown, and with woolly hair, such as forms the ideal personification of a Negro. The ugliest Negro tribes are confined to the equatorial countries; and on both sides of the equator, as we advance towards the more temperate zones, the persons of the inhabitants are more handsome and well formed.

1. The following is a description of the Negroes of the race of Acra, by Isert the Danish traveller.

"Almost all the Negroes are of a good stature, and the Acra Negroes have remarkably fine features. The contour of the face, indeed, among the generality of these people is different from that of Europeans: but at the same time faces are found among them, which, excepting the black colour, would in Europe be considered as beautiful. Commonly, how-

ever, they have something apish. The cheek bones and chin project very much, and the bones of the nose are smaller than in Europeans. This last circumstance has probably given rise to the assertion, that the Negro women flatten the noses of their children as soon as they are born. But noses may be seen among them, as much elevated and as regular as those of Europeans. Their hair is woolly, curled, and black; but sometimes red. When continually combed, it may be brought to the length of half a yard; but it can never be kept smooth *."

2. Barbot describes Negroes upon the Gold Coast, with features, in which the Negro conformation was reduced to an approach to European symmetry, the skin *indifferent black, with long curled hair sometimes reaching down to their shoulders;* the women for the most part having *high noses somewhat hooked, and long curling hair.*

3. The country between the Senegal and Gambia, and from Cape Verd as far as the boundaries of the Foulahs, is the abode of the nation of Yoloffs, or Yaloffs, who were formerly united under the dominion of the Bourb' Joloff, or Yoloff Emperor, but are now divided into several states. The Yoloffs are described by travellers as a very fine race of people: they are tall, well made, of middle stature; their countenances are ingenuous and agreeable, but have in some degree the flat nose and thick lips common to many Negro nations, though many of them have regular features. Their hair is crisp and woolly: their colour is a fine deep clear black. They are cheerful and indolent. They have a peculiar language, which is said to be harmonious. The circumstance, that the Yoloffs at the northern extremity of Negroland are of a deep black colour, has drawn the following remark from a traveller well acquainted with the nations of Africa.

"This race of Negroes, the most handsome and the finest black of all those dependent upon the government of the Senegal, proves that the deepest colour does not arise solely from the heat of the climate, nor the being more subjected to the vertical rays of the sun, but results from other causes. For the Joloffs are to the north of Nigritia; and the further you recede from them and approach towards the line, the black

* P. E. Isert; Reis na Dordrecht, 1790. Translated in Philos. Mag. vol. iii, p. 144.

colour of the Negroes becomes less and less strong and unmingled *."

4. The Tibboo are divided into six tribes, who occupy the country east of Fezzan, and between Fezzan and Bornoo. The following account of them is by Captain Lyon.

"The Tibboo females are light and elegant in form, and their graceful costume, quite different from that of the Fezzaners, is well put on. They have *aquiline noses*, fine teeth, and *lips formed like those of Europeans;* their eyes are expressive, and their colour is of *the brightest black.* There is something in their walk and erect manner of carrying themselves which is very striking. Their feet and ankles are delicately formed, and are not loaded with a mass of brass or iron, but have merely a light anklet of polished silver or copper, sufficient to show their *jetty* skin to more advantage: they also wear red slippers. Their hair is plaited on each side, in such a manner as to hang down on the cheeks like a fan, or rather in the form of a large dog's ear.

"The Tibboo of Bergoo seem to approach the Negroes in their physical character. They conceal themselves from the Arab hunters by kneeling on the ground, which is of the same colour as their skin, being black basalt. They are however of lighter complexions than other Negroes, and are handsomer people. The females wear their hair, which is *not very woolly,* in long plaits."

5. "The people of Berber," says Burckhardt, "are a very handsome race. The native colour seems to be *a dark red brown,* which, if the mother is a slave from Abyssinia, becomes a light brown in the children, and if from the Negro countries, extremely dark. The men are somewhat taller than the Egyptians, and are much stronger and longer limbed. Their features are not at all those of the Negro, the face being oval, the nose often perfectly Grecian, and the cheek bones not prominent. The upper lip is, however, generally somewhat thicker than is considered beautiful among northern nations, though it is still far from the Negro lip. Their legs and feet are well formed, which is seldom the case with Negroes. They have a short beard; their hair is bushy and strong, but not woolly: it lies in close curls when short, and when permitted to grow, forms itself into broad high tufts."

* Golberry, i, p. 75.

6. The term Nouba is given to all the blacks coming from the slave countries to the south of Sennaar. Speaking of these, Burckhardt observes, that their noses are less flat than those of the Negroes; their lips are less thick, and their cheek bones not so prominent. Their hair is generally similar to that of Europeans, but stronger and always curled; sometimes it is woolly. Their colour is less dark than that of Negroes, and has a coppery tinge *.

7. The Copts are well known to be the descendants of the old Egyptians. Many travellers have remarked among them a certain approximation to the Negro. Volney says, that they have a yellowish dusky complexion, with a puffed visage, swollen eyes, flat noses, and thick lips, bearing much resemblance to Mulattoes. M. Denon says he was much struck with the resemblance of the Copts to the old Egyptian sculptures, characterized by "flat foreheads, eyes half closed and raised up at the angles, high cheek bones, a broad flat nose, very short, a flattened mouth, placed at a considerable distance from the nose, thick lips, little beard, a shapeless body, crooked legs, without any expression in the contour, and long flat toes."

Mr. Ledyard, whose testimony is of the more value, as he had no theory to support, says, "I suspect the Copts to have been the origin of the Negro race; the nose and lips correspond with those of the Negroes. The hair, whenever I can see it among the people here (the Copts), is curled; not like that of the Negroes, but like the Mulattoes."

It seems that the complexion of the Copts is liable to considerable variations. Though it must be true, as M. Volney asserts in the passage above cited, that the Copts are generally of a dusky and yellowish colour, like the Abyssinians: yet we are assured by M. Belzoni, that some of them are nearly as fair as Europeans.

8. The complexion of the Hottentots is like that of the palest Negro, but still more dilute. Mr. Barrow observes, that it is of a yellowish brown, or of the hue of a faded leaf. The hair is of a very singular nature: it does not cover the whole surface of the scalp, but grows in small tufts at certain distances from each other, and when clipt short, has the appearance and

* Burckhardt's Travels, p. 312.

feel of a hard shoe-brush, except that it is curled and twisted into small round lumps, about the size of a marrowfat pea. When suffered to grow, it hangs on the neck in hard twisted tassels like fringe.

" The Hottentots are well-proportioned, erect, of a delicate and effeminate make; not muscular; their joints and extremities small; the face generally ugly, but different in different families; some having the nose remarkably flat, others considerably raised. Their eyes are of a deep chesnut colour, long and narrow, distant from each other; the inner angle being rounded, as in the Chinese, *to whom the Hottentot bears a striking resemblance.* The cheek bones are high and prominent, and, with the narrow pointed chin, form nearly a triangle. Their teeth are very white. The women when young are graceful and well made; the nipple is unusually large, and the areola much elevated; but immediately after the birth of the first child, the breast becomes flaccid and pendent, and in old age becomes greatly distended. The belly becomes protuberant, and the posteriors are covered with a huge mass of pure fat. That elongation of the nymphæ, which is well known to characterize the Hottentot women, has been falsely ascribed to art. It is a natural variety of conformation.

Mr. Burchell states the following characters as peculiar to the Hottentots. Hands and feet little; eyes so oblique, that lines drawn through the corners of each, would not coincide as being in the same plane, but would intersect as low down as the middle of the nose; end of nose wide and depressed; nostrils squeezed out of shape; chin long and forward; narrowness of the lower part of the face, a character of the race.

9. All the physical characters of the Hottentots are recognized in the Bushman. In the latter people all the deformities of the race are seen in an exaggerated degree; they are extremely ugly and diminutive; the middle size of the men being four feet six inches, and that of the women four feet.

Cuvier has given some valuable information on the anatomical peculiarities of this race, in his account of the dissection of the Bosjes woman, well known under the name of the Hottentot Venus. In this individual, the skull and the bones of the face presented a striking combination of the traits of the Negro with those of the Calmuck, the jaws projecting more

than in the Negro, the face being wider than in the Calmuck, and the nose flatter than in either, and in this respect approximating more to the monkey.

The characters of the Æthiopian variety are met with again in many of the inhabitants of the islands of the Indian and Pacific Oceans. In some instances, people of this description are the exclusive inhabitants; in others they are mixed with a totally different population; in others they are wholly wanting. They are termed in the islands of the Indian Archipelago, by the other inhabitants, Pua-pua, or blacks, in allusion to their complexion; and thence by Europeans they are denominated Papuas. The principal residence of the Papuas, strictly so called, is in the great islands of New Guinea and New Britain.

The skin of a Papua, from Sir E. Home's description of one brought home by Sir Stamford Raffles, is of a light colour, the woolly hair grows in small tufts, and each hair has a spiral twist. The forehead rises higher, and the hind head is not so much cut off. The nose projects more from the face; the upper lip is longer and more prominent; the lower lip projects forward from the lower jaw, to such an extent, that the chin forms no part of the face, the lower part of which is formed by the mouth. The buttocks are so much lower than in the Negro as to form a striking mark of distinction; but the calf of the leg is as high as in the Negro.

Besides the Papuas, who are characterized by black complexions and woolly hair, there are tribes in many of the Indian islands, who are as black as the Papuas, or nearly so, but have instead of woolly, rough but lank hair. According to M. Lesson, who has given the results of his own personal inquiries, these tribes formed the primitive population of the Indian Archipelago. They appear to have been supplanted in some islands, at various periods, by more powerful races, who have either extirpated them, or have driven them from the coasts into the mountainous and desert parts in the interior. They are yet to be found in all the wildest and most inaccessible tracts of Polynesia, under which term M. Lesson comprehends all the lands bordering on or contained in the Malayan Archipelago, reserving the name of Oceania for the remote groups of islands in the Pacific. The central parts of most of the Moluccas are still occupied by Haraforas or Alfoërs, the Philippines by tribes of the same description, whom the Spaniards

term Los Indios; Mindanao by the Negros del Monte; the interior of Madagascar by Virzimbers, of all which countries these appear to be the original inhabitants; in the interior of New Guinea, tribes of a similar description are termed by the Papuas, Endamênes. The Endamênes seen by M. Lesson had a repulsive physiognomy, flat noses, cheek bones projecting, large eyes, prominent teeth, long and slender legs, very black and thick hair, rough and shining, without being long. Their beards were very hard and very thick. These savages, whose skin is of a very deep dirty brown or black colour, go naked. They make incisions upon their arms and breasts, and wear in their noses pieces of wood nearly six inches long. Their character is taciturn, their physiognomy fierce, their motion uncertain and slow.

The Endamênes, confined in the interior of New Guinea, in the northern region of that country, still continue, according to M. Lesson, to be the sole possessors of the southern coast; if they reach to the northern limits of Torres' Straits, the supposition, that in former times they may have passed over the channel, and spread themselves in the vast regions of Terra Australis, becomes very probable. M. Lesson refers the Australians to the class of Alfourous.

The stature of the Australians is moderate, and often below the mean. The limbs among many tribes are slender, thin, and in appearance of disproportioned length; while some individuals, on the contrary, have them stout and well proportioned. Their hair is not woolly, it is hard, very black and thick; they wear it dishevelled, and in general short, in frizzled masses. Their beard is of the same nature with their hair; commonly rough, and tufted on the sides of their face. Their countenance is flattened, their nose very large, with nostrils placed almost transversely, thick lips, mouths of unproportioned width, teeth projecting, but of the finest enamel. Loose circular ears, very amply developed, and eyes half closed by the laxity of their upper eyelids, give to their physiognomy a savage and repulsive aspect. The colour of their skin, generally of a smoky black, varies in its hue, which is never very deep.

The shape of the head resembles that of the African Negro, but its harsher features are softened; the alveolar edge of the upper jaw projects perhaps in the same degree, but the bones are not so heavy and massive. The head rises to a greater

height at the coronal suture, and the chin does not recede as in the Negro. What is most remarkable in the skulls of New Hollanders, after their general but softened resemblance of the Negro cranium, is the projection of the superciliary ridges, which gives a scowling expression to the vacant orbit. The effect is produced by a singular and deep depression at the junction of the nasal bones with the frontal. The same peculiarity is observable in the crania of many Oceanic tribes. It is equally a feature in the entire Australian head; of which two specimens are preserved in the Hunterian Museum.

The inhabitants of Van Dieman's Land, or the Tasmanians, are a woolly-haired race. They are thus described by Anderson. "Their colour is a dull black, not quite so deep as that of the African Negroes. Their hair is perfectly woolly. Their noses, though not flat, are broad and full. The lower part of the face projects a good deal, as is the case of most Indians I have seen, so that a line let fall from the forehead would cut off a much larger portion than it would in an European. Their eyes are of a middling size, with the white less clear than in us. Their teeth are broad, but not equal nor well set. Their mouths are rather wide; but this appearance seems heightened by wearing their beards long and clotted with paint, in the same manner as the hair on their heads. In other respects they are well-proportioned, though the belly seems rather projecting. Their manners, he adds, resemble those of the New Hollanders in most particulars. They make huts of a similar kind, though their chief habitation is in hollow trees. They are without clothes, and cover their skins with dirt."

The Tasmanians are thus Papuas, while the New Hollanders are Alfourous.

II. *Of the meso-bregmate or Caucasian variety.*

1. It is unnecessary to adduce authorities to prove the general resemblance that exists among the inhabitants of Europe. The points in which one nation differs from another, are the following. Towards the north of Europe, a lighter complexion, with light hair, and high and large features, prevail; towards the south, a darker complexion, dark hair and eyes, and a more marked and expressive countenance.

2. The Circassians who inhabit the heights of Mount Caucasus, and the Georgians who dwell at its foot, admit of being

similarly contrasted. Both are the choicest specimens of the meso-bregmate variety; the former fair; the latter a dark complexioned race, but superior to the former in symmetry and beauty.

The Ossites on Mount Caucasus have a fine sanguine complexion. In external appearance, according to the description of Pallas, they exactly resemble the peasants in the north of Russia; they have in general, like them, either brown or light hair, occasionally also red beards.

3. The Afghans occupy a great part of the Persian empire. They approximate on the one hand to the northern Persians and Europeans, on the other to the Hindoos. "The Afghan women," says Mr. Elphinstone, "are described as large, compared to those of India, and very fair and handsome. The men are all of a robust make, and are generally lean, though bony and muscular. They have high noses, high cheek bones, and long faces. Their hair and beards are generally black, sometimes brown, and rarely red; their hair is always coarse and strong. They shave the middle part of their head, but wear the rest of their hair. The tribes near towns wear it short, but the rest have long and large locks hanging down on each side of the head. They wear long and thick beards."

In the northern parts of Persia the complexion of the people is fair. A writer who had travelled in the countries between Caucasus and Persia, and who was acquainted with the people of this frontier, mentions a slender form and blue eyes as characteristic of the female Persians. The Kinos are remarked to have a white complexion with animated features.

4. Mr. Frazer thus describes the people of Muscat, on the eastern coast of Arabia, below the Persian Gulf, and more particularly the natives of the celebrated Ormus. "The Arabs in colour resemble Mulattoes, are of a sickly yellow hue, with a deeper brownish tinge about the eyes, neck, and joints: some are very dark. The genuine Arabs, with some exceptions, are rather spare and active than athletic men. Those of the superior orders, who came under our observation, as the Shieks and their families, bore a strong characteristic resemblance to each other in features. The countenance was generally long and thin; the forehead moderately high, with a rounded protuberance near its top; the nose prominent and aquiline; the mouth and chin receding, giving to the line of profile a circular rather

than a straight character; the eye deep set under the brow, dark and bright; thin and spare, deficient in muscle, their limbs were small, particularly their hands, which were sometimes even of feminine delicacy; their beards were almost always of a deep black, artificially coloured, if not naturally so: a few wore them grizzled; and we observed an old man, whose beard of a milk-white colour he had dyed yellow, which, contrasted with a singular pair of blue eyes, had a very extraordinary effect.

" Les princesses, et les autres dames Arabes," says M. de la Roque, " qu'on m'a montré par le coin d'une tente, m'ont paru fort belles et bien faites. On peut juger par cellesci, et par ce qu'on m'en a dit, que les autres ne le sont guères moins: elles sont fort blanches, parce qu'elles sont toujours à couvert du soleil. Les femmes du commun sont extrêmement halées, *outre la couleur brune* et basanée qu'elles ont naturellement; je les ai trouvé fort laides dans toute leur figure, et je n'ai rien vû en elles que les agremens ordinaires, qui accompagnent une grande jeunesse."

The variety of complexion above described seems to be a natural deviation, and is not referable to any mixture of breeds. A brown or tawny yellow is the natural colour of the Arabs in some places. But there are races of Bedouins and other tribes of a still darker complexion, and even black or nearly so.

6. The form of the skull in the natives of Hindoostan and the Deccan presents no decided difference from the shape common among Europeans. The only character in the osteology of the Hindoo, which has drawn the attention of anatomists, is the length of the limbs, which is said to be greater in proportion to the trunk than that of other nations.

The people of the northern provinces of India are of lighter complexion than those of the south. Those of inferior caste are generally of darker complexion than the superior Hindoos. The people of Malabar are said to be darker than the natives of other provinces, and approach to, if not equal, the blackness of the natives of Guinea. The Mahrattas are of a yellow tint of complexion, and the natives of the mountainous tracts in the north are of very light colour, and approach to the complexion of Europeans. The Kattees, a race of high caste, are supposed to descend from a tribe on the banks of the Indus. The stature of the Kattee, according to Lieutenant M'Murdo, is larger than

common, often exceeding six feet: he is sometimes seen with light hair, and blue-coloured eyes. His frame is athletic and bony.

The following extract from Dr. Prichard will serve to show, that a physical character like that of the Caucasian variety appears again in the islands of the Southern Ocean.

The people of New Zealand and the Sandwich Isles, those of the Tonga Isles, and again the inhabitants of the Society Isles, Otaheite, and the Marquesas, display a regular gradation from a very dark to a light complexion. The complexion of the New Zealanders varies from a pretty deep black to an olive colour, or yellowish tinge; and the Sandwich Islanders are often of a very dark brown colour. In the Tonga Islands the general complexion is of a cast deeper than the copper-brown, though some have a true olive complexion, and individuals, principally females, are much fairer. In Otaheite, and the adjacent isles of the same group, the most beautiful, and at the same time the most variable, tribe of the whole race is found. "There," says Forster, "nature seems in the human species to follow that richness, luxuriance, and variety, which we have observed in the vegetable kingdom: she is not confined to a single type or model. The common people are of a dark colour, and degenerate towards the appearance of the natives of the New Hebrides; but the better sort have a complexion, which is less tawny than that of a Spaniard, and lighter than the fairest inhabitants of the East India Islands: in a word it is *white*, tinctured with a brownish yellow; however, not so strongly mixed, but that on the cheeks of the fairest of their women you may easily distinguish a spreading blush. From this complexion we find all the intermediate hues down to a brown, bordering the swarthy complexion of the race found in the New Hebrides. Their hair is commonly black and strong, flowing in beautiful ringlets. I saw but few with yellowish-brown or sandy hair. But in some instances the decided characters of the true sanguine complexion display themselves even here." Dr. Forster adds, that a single man in Otaha had perfectly red hair, a fairer complexion than the rest, and was sprinkled all over with freckles. Captain Wallis says, that "the hair was in some brown, in some red, and in others flaxen: but that in the children of both sexes it is generally flaxen." These marks of the fair, or sanguine complexion,

which in Otaheite are occasionally seen, appear to be almost general in the Marquesas, the inhabitants of which were thought by Captain Cook to be the finest race of people in the South Sea. "The women and children," he says, "in general terms, are as fair as some Europeans. Their hair, like ours, is of many colours, except red, of which I saw none." In the accounts, however, of Mendana's voyage, who discovered these islands, it is expressly said, that many of the people had red hair. It is observed, that the general colour among them was almost white, and that they had in person greatly the advantage of the Spaniards.

The texture of the hair is in general like that of the Javanese, but in some instances it varies. In some of the New Zealanders it is curling; the Tonga and Sandwich Islanders have occasionally bushy and frizzled hair.

The features of the Otaheitans are more soft and delicate, but appear to have a general resemblance to those of the islanders near the Indian continent. The face of these people is said to be handsome, but their noses somewhat flat. In the Tonga Isles, there are hundreds of truly European faces with aquiline noses. The most general trait in the whole race is a fulness of the nostrils, which reminds us of the bottle noses of the New Guinea Negroes.

III. *Of the platy-bregmate or Mongolian variety.*

1. Dr. Clarke has described in very strong terms the physical characters of the Kalmucks. "We saw a horde of these people, who were all quite naked, with their skins perfectly black. Their hair is coarse and black, their language guttural and harsh. Nothing is more hideous than a Kalmuck. High, prominent, and broad cheek bones; very little eyes, widely separated from each other; a flat and broad nose; coarse, greasy, jet-black hair, scarcely any eyebrows, and enormous prominent ears, compose no very inviting portrait."

"If we abstract the circumstance of colour," says Pallas, "a Mongole bears less resemblance to other races of men than a Negro bears to an European. The particular conformation of the race is most remarkable in the shape of the skull prevalent among the Kalmucks; but the Mongoles proper and the Bouriaks bear to the tribe last mentioned so great a resemblance, as well in their physical as in their moral and social characte-

ristics, that what can be predicated of one people is applicable to the rest."

"The Kalmucks are generally of middle stature: few are tall, and many are below the standard; the women especially are small. They are all well made, and I do not remember to have seen one deformed person among them. The only fault in shape, which is frequent among them, consists in an outward bending of their arms and legs, resulting from the practice of causing children to rest always in their cradles on a kind of saddle, and from the habit of riding on horseback almost as early as they are able to walk. The Kalmucks have generally short necks; their limbs are thin and lean: even the principal and more opulent men among them are seldom corpulent, in which they differ from many of the Kirgese and other Tartar nomades.

"The characteristic features of the Kalmucks are, eyes placed obliquely, the large angle of which descending towards the nose is slightly open and fleshy; eyebrows black, thin, and forming a low arch; a peculiar formation of the nose, which is generally flattened and squatted towards the forehead; cheek bones prominent; head and countenance very round. The ball of the eye is likewise very brown; the lips large and fleshy; the chin short; the teeth very white: they continue fine and sound even in old age. Their ears are of an enormous size, and loose from the head.

"From the relations of many travellers, we should be induced to believe that *all* the Kalmucks have ugly and hideous figures. On the contrary, we see as well among the men as among the women many round and beautiful countenances: we even see women, who have such regular and beautiful features that they would find a great number of admirers among Europeans."

The Kalmucks have the finest sense of smelling, the most perfect hearing, and an extraordinarily piercing sight.

2. Mr. Frazer thus describes the Tuckehs, one of the Turkoman races in the desert northward of the Elbergh range of mountains and the Steppe of Khaurezm.

"The Tuckehs have a great deal of the Mongolian physiognomy: many of the men were tall, stout, and well made; with scanty beards, eyes small, and drawn up at the corners; high cheek bones, and small flat noses. Some on the contrary

had handsome features, more resembling those of Europeans than Asiatics."

3. The persons of the Tungusians are thus described by Gmelin: "Les Tongouses ont le visage conformé à peu près comme les Kalmouckes; cependant ils l'ont un peu moins large; il m'a semblé qu'en général leur taille était peu élevée. Leurs cheveux sont noirs, et la plupart les portent tressés comme les Chinois."

4. Pallas thus describes the Northern Chinese. "Ils sont très bien formés dans leur jeunesse; on en voit beaucoup qui ont des figures très agréable, un beau teint, de petits yeux noirs qui forment l'angle, et des cheveux du plus beau noir. Cependant ils préférent ceux qui ont une figure mandshoure, c'est-à-dire, le visage large, de hautes mâchoires, un nez très large et d'énormes oreilles. Cette dernière conformation est propre aux Chinois, et presque générale parmi eux. Ils ont la barbe noire, et clair sémee; les gens âgés sont les seuls qui la laissent croître."

Mr. Barrow informs us, that the Chinese are somewhat taller and more slender than the Mantschoo Tartars. He adds, that "the small eye, elliptical at the end next the nose, is a predominant feature in both the Mantschoo and Chinese countenance, and they have both the same high cheek bones and pointed chins."

"We saw," observes Mr. Barrow, "women in China, though very few, that might pass for beauties even in Europe. The Malay features prevail in most: a small black or dark-brown eye; a short rounded nose, generally a little flattened: lips considerably thicker than in Europeans, and black hair is universal.

5. Mr. Turner has described the physical character of the Bhoteans, and his description may probably be regarded as referring to the Tibetans in general.

"The Bhoteans have invariably black hair, which it is the fashion to cut close to the head. The eye is a very remarkable feature of the face; small, black, with long pointed corners, as though stretched and extended by artificial means. Their eyelashes are so thin as to be scarcely perceptible, and the eyebrow is but slightly shaded. Below the eyes is the broadest part of the face, which is rather flat, and narrows from the cheek bone to the chin; a character of countenance first appearing to take

its rise among the Tartar tribes, but which is far more strongly marked in the Chinese. Their skins are remarkably smooth, and most of them arrive at a very advanced age before they can boast even the rudiments of a beard." He adds, "many of these mountaineers are more than six feet high. Taken altogether, they have a complexion not so dark by several shades as that of the European Portuguese." In describing the people of the mountainous districts to the northward of Bhotan, he observes, "I never beheld a more florid picture of health than was exhibited in the complexion of the mountaineers we met to-day; the women in particular, with their jet black hair, and clear, brisk, black eyes, had a ruddiness, which the most florid English rustic would in vain attempt to rival."

6. The physical character of the Japanese bears a strong resemblance to that of the Chinese: "they are well made (according to the description of Thunberg), active, free and easy in their motions, with stout limbs, although their strength is not to be compared with that of the northern inhabitants of Europe. The men are of the middling size, and in general not very corpulent; yet I have seen some that were fat. They are of a yellowish colour all over, sometimes bordering on brown, and sometimes on white. The lower class of people, who in summer, when at work, lay bare the upper part of their bodies, are sunburnt, and consequently brown. Ladies of distinction, who seldom go out into the open air without being covered, are perfectly white. It is by their eyes, that, like the Chinese, these people are distinguishable. These organs have not that rotundity which those of other nations exhibit, but are oblong, small, and are much deeper in the head, in consequence of which these people have almost the appearance of being pink-eyed. Their eyes are dark brown, or rather black, and the eyelids form in the great angle of the eye a deep furrow, which makes the Japanese look as if they were sharper sighted, and discriminates them from other nations. The eyebrows are also placed somewhat higher. Their heads are in general large, and their necks short; their hair black, thick, and shining, from the use they make of oils. Their noses, although not flat, are yet rather thick and short."

7. The inhabitants of Transgangetic India, and of the peninsula of Malacca, exhibit a marked physical affinity to the

Chinese. The same character again is strikingly observable in the inhabitants of many of the Indian islands. "The forehead of the Javanese," says Sir T. S. Raffles, "is high, the eyebrows well marked and distant from the eyes, which are somewhat Chinese or rather Tartar in the formation of the inner angle. The colour of the eye is dark; the nose small, and somewhat flat. The beard very scanty; the hair of the head generally lank and black."

Let us now pass to the American continent.

The inhabitants of America are in stature generally superior to the nations of Europe, Asia, and Africa, though to this remark there exist some notable exceptions. Their bodies are remarkably smooth, and devoid of pilar hair; while that of their heads is generally lank, though in some few instances curled, but in none crisp or woolly. Their colour, though not uniform, some being white with a florid complexion, and even with red or yellow hair, while others are nearly black, is yet subject to fewer varieties than we might expect from the diversity of the climates they inhabit, and a coppery hue prevails more extensively among them than in any other department of the human species.

"The Indians of New Spain," observes Humboldt, "bear a general resemblance to those who inhabit Canada, Florida, Peru, and Brazil. They have the same swarthy and copper colour, straight and smooth hair, small beard, squat body, long eye, with the corner directed upwards towards the temples, expressions of gentleness in the mouth strongly contrasted with a gloomy and severe look." "Over a million and a half of square leagues, from Terra del Fuego to the river St. Lawrence and Behring's Straits, we are struck at the first glance with the general resemblance in the features of the inhabitants. We think that we perceive them all to be descended from the same stock, notwithstanding the prodigious diversity of languages which separates them from one another." "In the faithful portrait which an excellent observer, M. Volney, has drawn of the Canada Indians, we undoubtedly recognize the tribes scattered in the Savannahs of the Rio Apuro and the Corones. The same style of features exists in both Americas." The nations of South America have in general flatter faces, and many of them a shorter and broader shape of body than the North Americans.

It has been remarked by several writers, that the cheek bones of the Americans are almost as prominent as those of the Mongoles. In other respects the physical characters of these races are said to resemble each other. "The analogy between them," says Humboldt, "is particularly evident in the colour of the skin and hair, in the want of beard, the shape of the cheek bones, and the direction of the eyes. We cannot refuse," he adds, "to admit, that the human species does not contain races resembling one another more nearly than the Americans, the Mongoles, the Mantchoos, and the Malays."

The opinion of Humboldt has been confirmed by that of Von Spix and Von Martius. These writers have made the following remarks upon the resemblance between the native Americans and the Chinese colonists settled in the Brazils. "The physiognomy of the Chinese was particularly interesting to us, and was in the sequel still more so, because we thought we could perceive in them the fundamental lines which are remarked in the Indians. The figure of the Chinese is, indeed, rather more slender, the forehead broader, the lips thinner and more alike, and the features in general more delicate and mild, than those of the American who lives in woods; yet the small not oblong but roundish angular rather pointed head, the broad crown, the prominent sinus frontales, the low forehead, the pointed and projecting cheek bones, the oblique position of the small narrow eyes, the blunt, proprotionately small, broad flat nose, the thinness of the hair on the chin and the other parts of the body, the long smooth black hair of the head, the yellowish or bright reddish tint of the skin,—are all characteristics common to the physiognomy of both races. The mistrustful cunning, and as it is said often thievish character, and the expression of a mean way of thinking, and mechanical disposition, appear in both in the same manner. In comparing the Mongole physiognomy with the American, the observer has opportunity enough to find traces of the series of developments, through which the Eastern Asiatic had to pass under the influence of the climate, in order at length to be transformed into an American."

Among the existing American races, two varieties occur in the figure of the head. The more prevalent one is flattening and depression of the forehead. The rarer is an acuminated elevation of the vertex, which is narrowed so as to give the

face a triangular outline, the apex upwards. The latter is met among the Esquimaux, as the excess of deviation to which that race is disposed to run. The former occurs in different points: it is observed among the Caribs, and among the natives of the district adjoining Nootka Sound. A remarkable practice goes with it: the tribe endeavours artificially to increase its characteristic peculiarity, and the heads of their infants are compressed by an elaborate process. It is probable that the effect so obtained is inconsiderable. But it is curious to remark the universal prevalence of a disposition to exaggerate national contour. The Mongole and American, with a rare and late growth of beard, remove the little they possess; while among Caucasian nations, the beard, naturally copious, is or has been nourished as an emblem of rank, of wisdom, of sanctity. The beauty of the Greek ideal, is the heightened representation of a national form, and might not interest a Scythian eye.

The Esquimaux are a race separated into a great number of hordes, and occupying the shores of the Polar Sea, from Asia, where they exist northwards of Kamschatka, to Greenland in the west. By some, they have been classed with the Samoiedes as a separate branch of the human family, under the name of the Hyperborean race. Short in stature, of a dirty pale or yellowish brown complexion, with lank black hair, their heads, which have the general character of the Mongolian race, run out in many instances into a peculiar form at the vertex. The face, instead of being of a somewhat flattened oval form, as in most Europeans, is of a lozenge shape, rising like one of the faces of a pyramid almost to a point, with a ridge running backward from the summit of the frontal bone over the vertex, and towards the occiput.

Many skulls have been found in ancient tombs in various parts of the United States, which resemble the Esquimaux more than the present, or rather the late inhabitants of the country.

The most remarkable addition that has of late years been made to our knowledge of the various forms which the human race has been cast in, has been the discovery, in Peruvian burying places, of skulls which combine in an extraordinary degree the platy-bregmate and steno-bregmate features,—the flat head, which is a characteristic American variety, with the narrowness of the cranium, which belongs to the Æthiopian.

The flatness, however, goes to the extent of almost suppressing the forehead, which retreats nearly horizontally from the superciliary ridges. Several specimens of these crania may be seen in the Museum of the Royal College of Surgeons in London.

Mr. Pentland obtained these skulls in 1827, in the province of Upper Peru, now called Bolivia. He supposed them to belong to an extinct race of men. "I found them," says Mr. Pentland in his communication to M. Tiedemann, "in the ancient graves called Huescas, in the great Alpine valley of Titicaca, which is likewise remarkable for being the country in which civilization, planted by the Peruvians, flourished to a degree unrivalled among the other tribes of the New World. These sepulchres have the form of high round towers, and in some places are constructed of enormous masses of masonry. The stones are very carefully and skillfully arranged, in a manner similar to that observed in the old structures of Greece and Rome, named by our antiquarians, Cyclopean. I have met with them only in the valley of Titicaca, which extends from the seventeenth to the nineteenth degree of latitude south, and on the skirts of the Andes, which form that valley. They occur in the greatest abundance in the provinces of La Paz, Oruro, Pacages, and Carangas. I examined several hundreds of these sepulchres, and in all of them found human skeletons, and in all the skull had the same singular shape. The skeletons are in a state of excellent preservation, a circumstance attributable to the great dryness of the climate, the country being situated about two thousand toises above the level of the sea. The skeletons belonged to persons of all ages, from the youngest child to the oldest man. All the heads, young and old, had the same form."

APPENDIX.

CHAPTER III.

The appearance of transverse cross shadows in muscular fibres, the discovery of which I have attributed to Dr. Hodgkin and Mr. Lister, was known to Fontana, who figures it with perfect accuracy.

It seems that Prochaska first observed these lines, and supposed them to be "impressions superficielles que font les vaisseaux, les cylindres cellulaires, et peut-être aussi les nerfs."

Fontana, pursuing the subject, saw the lines exactly as they are described by Dr. Hodgkin, and as I have seen them in Mr. Lister's microscope. They are faithfully represented in plate vi, fig. 6, appended to his "Traité sur le Vénin de la Vipere, &c."

Fontana went further, and analyzed the packets of muscular tissue which have the appearance adverted to, till he came to the primitive fibre, where it is still discernible.

"En décomposant peu à peu le muscle avec des aiguilles ou des pointes très aigues, ou parvient enfin à le resoudre en fils très fins, qui ne sont plus divisibles en d'autres moindres, quelque soin qu'on y porte. J'appellerai ces filamens *fils charnus primitifs*. Quelques centaines de ces fils unis ensemble forment un faisceau simple, que j'appellerai *faisceau charnu primitif*. Le muscle résulte enfin de l'assemblage d'un grand nombre de ces faisceaux. Le figure vii [planche vi] représente un faisceau charnu primitif.—Les fils charnus primitifs sont des cylindres solides, egaux entre eux, et marqués visiblement à distances égales, de petits signes, comme d'autant de petits diaphragmes, ou rides."—*Op. citat.* vol. ii, p. 228.

CHAPTER IV.

SECTION III.

The experiments of Dr. Addison and Mr. Morgan may be viewed as throwing a valuable light upon the subject of absorption of poisons.

The reader will find, on referring to page 80 of this volume, a body of evidence to prove that the stronger vegetable poisons, applied to a natural surface, or introduced into a wound, do not affect the system through the nerves or the absorbents of the part. The conclusions drawn from these researches were, that the poisons enter the circulation through the coats of the blood-vessels, and produce their effect by being carried to the brain mixed with the blood. Of the correctness of the first of these conclusions there can be no doubt: the latter, our authors had *gone some way* to show to be without foundation. They imagined and performed the ingenious experiment of partially alternating the cerebral circulations of two animals, one of which was poisoned; — contriving that some of the blood of an animal poisoned with strychnine should be propelled by its own heart into the carotid of another. The first died, while the second was unaffected by the poison. The following are the words, in which Dr. Addison and Mr. Morgan describe the experiment.

"Two large half-bred bull dogs, each weighing about forty pounds, were the animals selected for the operation. The carotid artery of each dog having been laid bare on one side, and separated from its connections with surrounding parts to the extent of three inches, temporary ligatures were applied above and below, and the arteries were divided between them, as in a former case; appropriate brass tubes were then attached to the extremities of the vessels, and the necks of the two animals being held and closely bound together, the divided arteries were, without the least difficulty, re-connected, and the circulation reversed.

"One of the dogs was then inoculated on the back with a concentrated preparation of strychnine, which had been found upon other occasions to produce death in these animals in about three minutes and a half.

"In three minutes and a half the inoculated animal exhibited the usual tetanic symptoms which result from the action of this poison, and died in a little less than four minutes afterwards, *viz.* about seven minutes from the time at which the poison was inserted, during the whole of which time a free and mutual interchange of blood between the two was clearly indicated by the strong pulsation of the denuded vessels throughout their whole course.

"The arteries were next secured by ligature, and the living was separated from the dead animal; but neither during the operation, nor at any subsequent period, did the survivor show the slightest symptom of the action of the poison upon the system.

"From these, then," they proceed to say, "and from many other similar experiments which it would be needless to instance, we have been led to the conclusion, that all poisons, and perhaps indeed all agents, influence the brain and general system, through an impression made upon the sentient extremities of the nerves, and not by absorption and direct application to the brain."

Their conclusions are open to the following criticism.

In the first place, it is possible that the dog into which the poison was not directly introduced did not die, because the quantity which reached its brain from one carotid of the other dog, was not *enough*.

In the second place, the other dog may have died through the direct operation of the larger quantity of poisoned blood on its brain, which three arteries (the remaining carotid and two vertebrals) carried thither.

Two experiments (the practicability of which is shown by the recently published experiments of Sir Astley Cooper on ligature of the cerebral arteries) are still wanting. One, in which the brain of an unpoisoned dog should be *entirely* (or nearly so) supplied with blood from the circulation of poisoned dogs; and the other, in which the brain of a poisoned dog should (the conditions being reversed) be *wholly* supplied from unpoisoned animals. Till these experiments are tried, it would be presumptuous to say what would be their results. It is possible (contrary to Dr. Addison's and Mr. Morgan's opinions) that the animal indirectly poisoned would die, and that the animal directly poisoned would live.

But supposing the opposite results to ensue, and the animal directly poisoned to die, and the other to recover, a doubt would still remain as to how the poison had operated on the first. If the circulation through the brain could be proved by such experiments not to be the channel of poisoning, would it not still be making a step beyond what inductive logic authorises to conclude, that the mortal impression is made upon

the *extremities of nerves?* It seems to me *possible*, that the nerves may have no exclusive concern in the matter; and that the poison, after all, *may* act by unvitalizing the whole organization, its influence being diffused generally. It is possible that experiments on plants may clear this doubt.

CHAPTER V.

SECTION III.

In this and the preceding section it is laboriously proved, that the production of chyme is effected by the chemical agency of the gastric juice; which, on the authority of Spallanzani, is stated to be a solvent when warm, an antiseptic when cold; and, on the authority of Dr. Prout, to be uniformly acidulous, the acid being principally the muriatic. These conclusions have been confirmed by the capital observations of Dr. Beaumont, in a case which opportunely fell under the observation of one of so much judgment, and of so philosophical a mind. The particulars are so interesting, and throw so much additional light upon the subject, that the reader will not object, I am persuaded, to a detailed account of this instance.

Dr. Beaumont, while stationed at Michillimachinac, in the Michigan territory, in 1822, in the military service of the United States, was called upon to take charge of Alexis St. Martin, a young Canadian of eighteen years of age, good constitution, and robust health, who had been accidentally wounded by the discharge of a musket on the 6th of June, 1822.

The charge, consisting of duck-shot, was received in the left side, at the distance of one yard from the muzzle of the gun. The contents entered posteriorly, and in an oblique direction, forward and inward; literally blowing off integuments and muscles to the size of a man's hand, fracturing and carrying away the anterior half of the sixth rib, fracturing the fifth, lacerating the lower portion of the left lobe of the lungs, the diaphragm, and perforating the stomach.

On the fifth day, sloughing took place; lacerated portions of the lung and stomach separated, and left a perforation into the

latter large enough to admit the whole length of the middle finger into its cavity, and also a passage into the chest half as large as his fist. Violent fever and further sloughing ensued; and for seventeen days every thing swallowed passed out through the wound, and the patient was kept alive chiefly by nourishing injections. By and by the fever subsided, the wound improved in appearance; and after the fourth week the appetite became good, digestion regular, and the health of the system complete. The orifice, however, never closed; and at every dressing the contents of the stomach flowed out, and its coats frequently became everted, or protruded so far as to equal in size a hen's egg; but they were always easily returned.

St. Martin, during the ensuing year, suffered extremely with exfoliations of the injured ribs; but at the expiration of that time he had recovered, and the wound was healed all but the perforation of the stomach, which was now two inches and a half in circumference. For some months the food could be retained only by constantly wearing a compress and bandage; then a small fold or doubling of the villous coat began to appear, which gradually increased till it filled the aperture and acted as a valve, so as completely to prevent any efflux from within, while it admitted of being easily pushed back by the finger from without. In 1833, which is the date of Dr. Beaumont's work, the orifice of the wound remained in the same state as in 1824. Dr. Beaumont's observations were begun in May 1825, and continued for four or five months; were resumed in August 1829, and continued till March 1831; and from November 1832 to March 1833.

Dr. Beaumont describes the aperture in St. Martin's stomach as situated about three inches to the left of the cardia. When the stomach was nearly empty, he was able to examine its cavity to the depth of five or six inches by artificial distension. When it was entirely empty, the stomach was always contracted on itself, and the valve generally forced out of the orifice, together with a portion of the mucous membrane equal in bulk to a hen's egg. After sleeping for a few hours on the left side, the protruded portion became so much larger as to spread over the neighbouring integuments five or six inches in circumference, fairly exhibiting the natural rugæ, villous membrane, and mucous coat lining the gastric cavity. This appearance is almost invariably exhibited in the morning before rising from bed.

Dr. Beaumont found it easy to obtain the gastric juice. The introduction of any foreign substance, as the tube of a thermometer, into the empty stomach, caused it to flow immediately. It was found to be transparent, inodorous, saltish, and acidulous to the taste: it consisted of water, containing free muriatic and acetic acids, phosphates, and muriates, with bases of potassa, soda, magnesia, and lime; and an animal matter, soluble in cold water, but insoluble in hot. The following experiment satisfactorily shows the seat and nature of the appetite of hunger.

"To ascertain whether the sense of hunger would be allayed without the food being passed through the œsophagus, he fasted from breakfast time till 4 o'clock, P. M., and became quite hungry. I then put in at the aperture three and a half drachms of *lean, boiled beef*. The sense of hunger immediately subsided, and stopped the borborygmus, or croaking noise, caused by the motion of air in the stomach and intestines, peculiar to him since the wound, and almost always observed when the stomach is empty."

Of the Appearance of the Villous Coat of the Stomach.

"The inner coat of the stomach, in its natural and healthy state, is of a light, or pale pink colour, varying in its hues, according to its full or empty state. It is of a soft, or velvet-like appearance, and is constantly covered with a very thin, transparent, viscid mucus, lining the whole interior of the organ.

"Immediately beneath the mucous coat, and apparently incorporated with the villous membrane, appear small, spheroidal, or oval-shaped glandular bodies, from which the mucous fluid appears to be secreted.

"By applying aliment, or other irritants, to the internal coat of the stomach, and observing the effect through a magnifying glass, innumerable minute lucid points, and very fine nervous or vascular papillæ, can be seen arising from the villous membrane, and protruding through the mucous coat, from which distils a pure, limpid, colourless, slightly viscid fluid. This *fluid*, thus excited, is invariably distinctly acid. The *mucus* of the stomach is less fluid, more viscid or albuminous, semi-opaque, sometimes a little saltish, and does not possess the slightest character of acidity. On applying the tongue to the mucous coat of the stomach, in its empty, unirritated state, no acid taste can be perceived. When food or other irritants have

been applied to the villous membrane, and the gastric papillæ excited, the acid taste is immediately perceptible. These papillæ, I am convinced, from observation, form a part of what is called by authors the villi of the stomach. Other vessels, perhaps absorbing as well as secretory, compose the remainder. That some portion of the villi form the excretory ducts of the vessels, or glands, I have not the least doubt, from innumerable ocular examinations of the process of secretion of gastric juice. The invariable effect of applying aliment to the internal but exposed part of the gastric membrane, when in a healthy condition, has been the exudation of the solvent fluid from the above-mentioned papillæ. Though the *apertures* of these vessels could not be seen, even with the assistance of the best microscopes that could be obtained, yet the points from which the fluid issued were clearly indicated by the gradual appearance of innumerable very fine, lucid specks, rising through the transparent mucous coat, and seeming to burst, and discharge themselves upon the very points of the papillæ, diffusing a limpid, thin fluid over the whole interior gastric surface. This appearance is conspicuous only during alimentation, or chymification. These lucid points, I have no doubt, are the termination of the excretory ducts of the gastric vessels or glands, though the closest and most accurate observation may never be able to discern their distinct apertures.

"The fluid, so discharged, is absorbed by the aliment in contact, or collects in small drops, and trickles down the sides of the stomach, to the more depending parts, and there mingles with the food, or whatever else may be contained in the gastric cavity. This fluid, the efficient cause of digestion — the true gastric juice of Spallanzani, I have no doubt — has generally been obtained, for experiment, by mechanical irritation of the internal coat of the stomach, produced by the introduction of a gum-elastic tube, through which it has been procured.

"The gastric juice never appears to be accumulated in the cavity of the stomach while fasting; and is seldom, if ever, discharged from its proper secerning vessels, except when excited by the natural stimulus of aliment, mechanical irritation of tubes, or other excitants. When aliment is received, the juice is given out in exact proportion to its requirements for solution, except when more food has been taken than is necessary for the wants of the system.

"When mechanical irritation by a non-digestible substance, as the elastic tube, stem of the thermometer, &c. has been used, the secretion is probably less than when the irritation has been produced by such substances as are readily dissolved in the gastric juice. Alimentary stimulus, when taken into the stomach, is diffused over the whole villous surface, and excites the gastric vessels, generally, to exerete their fluids copiously; whereas the irritation of tubes, &c. is local, and produces only a partial excitement of the vessels, and a scanty flow of the gastric juice. Hence the slowness in obtaining the clear fluid from the empty stomach through the tube. I have never, on numerous trials, been able to obtain, at any one time, more than one and a half or two ounces of this fluid, after the stomach had disposed of its alimentary matters, however long the period of abstinence had been. The discharge of this small quantity has generally been excited by the introduction of the tube. Ten, fifteen, or more minutes, were necessary to collect even this small quantity. Whenever fluid was obtained in larger quantity, as was sometimes the case, it invariably contained more than the usual quantity of mucus.

"On viewing the interior of the stomach, the peculiar formation of the inner coats are distinctly exhibited. When empty, the rugæ appear irregularly folded upon each other, almost in a quiescent state, of a pale pink colour, with the surface merely lubricated with mucus. On the application of aliment, the action of the vessels is increased, the colour brightened, and the vermicular motions excited. The small gastric papillæ begin to discharge a clear transparent fluid (the alimentary solvent), which continues abundantly to accumulate as aliment is received for digestion.

"If the mucous covering of the villous coat be wiped off with a sponge or handkerchief during the period of chymification, the membrane appears roughish, of a deep pink colour at first; but in a few seconds the follicles and fine papillæ begin to pour out their respective fluids, which, being diffused over the parts abraded of mucus, restore to them their peculiar soft and velvet-like coat, and pale pink colour, corresponding with the undisturbed portions of the membrane; and the gastric juice goes on accumulating, and trickles down the sides of the stomach again.

"If the membrane be wiped off when the stomach is empty,

or during the period of fasting, a similar roughness and deepened colour appear, though in a less degree; and the mucous exudation is more slowly restored. The follicles appear to swell more gradually. The fluids do not accumulate in quantity sufficient to trickle down, as during the time of chymification. The mucous coat only appears to be restored.

"The foregoing, I believe to be the natural appearances of the internal coat of the stomach in a healthy condition of the system.

"In disease, or partial derangement of the healthy function, this membrane presents various and essentially different appearances.

"In febrile diathesis, or predisposition, from whatever cause —obstructed perspiration, undue excitement by stimulating liquors, overloading the stomach with food — fear, anger, or whatever depresses or disturbs the nervous system — the villous coat becomes sometimes red and dry, at other times pale and moist, and loses its smooth and healthy appearance; the secretions become vitiated, greatly diminished, or entirely suppressed; the mucous coat scarcely perceptible; the follicles flat and flaccid, with secretions insufficient to protect the vascular and nervous papillæ from irritation.

"There are sometimes found, on the internal coat of the stomach, eruptions or deep red pimples: not numerous, but distributed here and there upon the villous membrane, rising above the surface of the mucous coat. These are at first sharp-pointed and red, but frequently become filled with white purulent matter. At other times, irregular, circumscribed, red patches, varying in size or extent, from half an inch to an inch and a half in circumference, are found on the internal coat. These appear to be the effect of congestion in the minute blood vessels of the stomach. There are also seen, at times, small aphthous crusts in connection with these red patches. Abrasions of the lining membrane, like the rolling up of the mucous coat into small shreds or strings, leaving the papillæ bare, for an indefinite space, is not an uncommon appearance.

"These diseased appearances, when very slight, do not always affect, essentially, the gastric apparatus. When considerable, and particularly when there are corresponding symptoms of disease, as dryness of the mouth, thirst, accelerated pulse, &c. no gastric juice can be extracted, not even on the

application of alimentary stimulus. Drinks received are immediately absorbed, or otherwise disposed of: none remaining in the stomach ten minutes after being swallowed. Food, taken in this condition of the stomach, remains undigested for twenty-four or forty-eight hours, or more, increasing the derangement of the whole alimentary canal, and aggravating the general symptoms of disease.

"After excessive eating or drinking, chymification is retarded; and although the appetite be not always impaired at first, the fluids become acrid and sharp, excoriating the edges of the aperture; and almost invariably produce aphthous patches, and the other indications of a diseased state of the internal membrane mentioned above. Vitiated bile is also found in the stomach under these circumstances; and flocculi of mucus are much more abundant than in health.

"Whenever this morbid condition of the stomach occurs, with the usual accompanying symptoms of disease, there is generally a corresponding appearance of the tongue. When a healthy state of the stomach is restored, the tongue invariably becomes clear."

Motions of the Stomach.

"The ordinary course and direction of the revolutions of the food are, first, after passing the œsophageal ring, from right to left, along the small arch; thence, through the large curvature, from left to right. The bolus, as it enters the cardia, turns to the left; passes the aperture; descends into the splenic extremity; and follows the great curvature towards the pyloric end. It then returns in the course of the smaller curvature, makes its appearance again at the aperture, in its descent into the great curvature, to perform similar revolutions.

"Such I have ascertained to be the revolutions of the contents of the stomach, from being able to identify particular portions of food, and from the fact, that the bulb of the thermometer, which has been frequently introduced during chymification, invariably indicates the same movements. These revolutions are completed in from one to three minutes. They are probably induced, in a great measure, by the circular or transverse muscles of the stomach, as indicated by the spiral motion of the stem of the thermometer, both in descending to the pyloric portion, and ascending to the splenic. These motions

are slower at first than after chymification has considerably advanced.

"While these revolutions of the contents of the stomach are progressing, the trituration or agitation is also going on. There is a perfect admixture of the whole ingestæ during the period of alimentation and chymification. There is nothing of the distinct lines of separation between old and new food, and peculiar central or peripheral situation of crude, as distinguished from chymified aliment, said to have been observed by Philip, Magendie, and others, in their experiments on dogs and rabbits, to be seen in the human stomach, at least in that of the subject of these experiments. The whole contents of the stomach, until chymification be nearly complete, exhibit a heterogeneous mass of solids and fluids; hard and soft; coarse and fine; crude and chymified; all intimately mixed, and circulating promiscuously through the gastric cavity, like the mixed contents of a closed vessel, gently agitated, or turned in the hand.

"If a mouthful of some tenacious food be swallowed, after digestion is considerably advanced, it will be seen passing the opening to the great curvature; and in the course of about one and a half or two minutes it will reappear, with the general circulating contents, more or less broken to pieces, or divided into smaller pieces, and very soon loses its identity. This agitating motion has the effect, and is undoubtedly designed, to break up the bolus, as well as to separate the external and chymified portion of the particles of food, and allow the undigested portions to come in contact with the gastric juice, their proper solvent. If the motions were simply revolutionary, the central portions would retain their situation until the outer, or chymified part, had passed into the duodenum in successive parcels; which, it is evident, would very much retard the process of digestion.

"As the food becomes more and more changed from its crude to its chymified state, the acidity of the gastric fluids is considerably increased; more so in vegetable than animal diet; and the general contractile force of the muscles of the stomach is augmented in every direction; giving the contained fluids an impulse towards the pylorus.

"It is probable, that from the very commencement of chy-

mification — from the time that food is received in the stomach —until that organ becomes empty, portions of chyme are constantly passing into the duodenum, through the pyloric orifice, as the mass is presented at each successive revolution. I infer this, from the fact that the volume is constantly decreasing. This decrease of volume, however, is slow at first; but is rapidly accelerated towards the conclusion of digestion, when the whole mass becomes more or less chymified. This accelerated expulsion appears to be effected by a peculiar action of the transverse muscles, or rather of the transverse band, as described by Spallanzani, Haller, Cooper, Sir E. Home, and others, in their experiments on animals. This band is situated near the commencement of the more conically-shaped part of the pyloric extremity, three or four inches from the smaller end. In attempting to pass a long glass thermometer tube, through the aperture, into the pyloric portion of the stomach, during the latter stages of digestion, a forcible contraction is first perceived at this point, and the bulb is stopped. In a short time, there is a gentle relaxation, when the bulb passes without difficulty, and appears to be drawn, quite forcibly, for three or four inches, towards the pyloric end. It is then released, and forced back, or suffered to rise again; at the same time giving to the tube a circular or rather spiral motion, and frequently revolving it completely over. These motions are distinctly indicated, and strongly felt, in holding the end of the tube between the thumb and finger; and it requires a pretty forcible grasp to prevent it from slipping from the hand, and being drawn suddenly down to the pyloric extremity. When the tube is left to its own direction, at these periods of contraction, it is drawn in, nearly its whole length, to the depth of ten inches; and when drawn back, requires considerable force, and gives to the fingers the sensation of a strong suction power, like drawing the piston from an exhausted tube. This ceases as soon as the relaxation occurs, and the tube rises again, of its own accord, three or four inches, when the bulb seems to be obstructed from rising further; but if pulled up an inch or two, through the stricture, it moves freely in all directions in the cardiac portions, and mostly inclines to the splenic extremity, though not disposed to make its exit at the aperture.

"Above the contracting band, and towards the splenic por-

tion of the stomach, the suction or grasping motion is not perceptible; but when the bulb is pushed down to this point, it is distinctly felt to be grasped, and confined in its movements.

"These peculiar motions and contractions continue until the stomach is perfectly empty, and not a particle of food or chyme remains; when all becomes quiescent again.

"If the bulb of the thermometer be suffered to be drawn down to the pyloric extremity, and detained there for a short time, or if the experiment be repeated too frequently, it causes severe distress, and a sensation like cramp, or spasm, which ceases on withdrawing the tube, but leaves a sense of soreness and tenderness at the pit of the stomach.

"These peculiar contractions and relaxations, mentioned above, succeed each other, at irregular intervals, of from two to four or five minutes. Simultaneously with the contractions, there is a general shortening of the fibres of the stomach. This organ contracts upon itself in every direction, and its contents are compressed with much force. The valvular portion of the stomach is firmly thrust into the aperture; closing the orifice; preventing the egress of aliment; and obstructing the view of the interior. During the intervals of relaxation, the rugæ perform their vermicular actions, the undulatory motions of the fluids continue, and the alimentary and chymous mass appear, revolving as before, promiscuously mixed, through the splenic and cardiac portions.

"All these facts, taken together, will, I think, rationally admit of the following explanation. The longitudinal muscles of the whole stomach, with the assistance of the transverse ones of the splenic and central portions, carry the contents into the pyloric extremity. The circular or transverse muscles contract progressively, from left to right. When the impulse arrives at the transverse band, this is excited to a more forcible contraction, and, closing upon the alimentary matter and fluids, contained in the pyloric end, prevents their regurgitation. The muscles of the pyloric end, now contracting upon the contents detained there, separate and expel some portion of the chyme. It appears that the crude food excites the contractile power of the pylorus, so as to prevent its passage into the duodenum; while the thinner chymified portion is pressed through the valve into the intestine. After the contractile impulse is carried

to the pyloric extremity, the circular band, and all the transverse muscles, become relaxed, and a contraction commences in a reversed direction, from right to left, and carries the contents again to the splenic extremity, to undergo similar revolutions.

"It would appear, then, that the discharge of the chyme from the stomach is effected by mechanical impulse. But I confess I do not like to give an opinion. I state the circumstances as they have occurred. The idea of mechanical force, I admit, is liable to objection; but, perhaps, not more so than that of the selecting power of the pylorus. Whatever bias I may have in favour of the former method, has been forced upon me by the deductions of experiment and observation."

As a last extract from Dr. Beaumont's valuable book, I give the following experiment.

"Aug. 7. At 11 o'clock, A. M., after having kept the lad fasting for seventeen hours, I introduced the glass tube of a thermometer (Fahrenheit's) through the perforation into the stomach, nearly the whole length of the stem, to ascertain the natural warmth of the stomach. In fifteen minutes, or less, the mercury rose to 100°, and there remained stationary. This I determined by marking the height of the mercury on the glass with ink, as it stood in the stomach, and then withdrawing it, and placing it on the graduated scale again.

"I now introduced a gum-elastic (caoutchouc) tube, and drew off one ounce of pure gastric liquor, unmixed with any other matter, except a small proportion of mucus, into a three ounce vial. I then took a solid piece of boiled, recently salted, beef, weighing three drachms, and put it into the liquor in the vial; corked the vial tight, and placed it in a saucepan, filled with water, raised to the temperature of 100°, and kept at that point, on a nicely-regulated sand bath. In forty minutes digestion had distinctly commenced over the surface of the meat. In fifty minutes the fluid had become quite opaque and cloudy; the external texture began to separate and become loose. In sixty minutes chyme began to form.

"At 1 o'clock, P. M. (digestion having progressed with the same regularity as in the last half hour), the cellular texture seemed to be entirely destroyed, leaving the muscular fibres loose and unconnected, floating about in fine small shreds, very tender and soft.

"At 3 o'clock, the muscular fibres had diminished one half, since last examination, at 1 o'clock.

"At 5 o'clock, they were nearly all digested; a few fibres only remaining.

"At 7 o'clock, the muscular texture was completely broken down; and only a few of the small fibres floating in the fluid.

"At 9 o'clock, every part of the meat was completely digested.

"The gastric juice, when taken from the stomach, was as clear and transparent as water. The mixture in the vial was now about the colour of whey. After standing at rest a few minutes, a fine sediment, of the colour of the meat, subsided to the bottom of the vial.

"At the same time that I commenced the foregoing experiment, I suspended a piece of beef, exactly similar to that in the vial, into the stomach, through the aperture.

"At 12 o'clock, M., withdrew it, and found it about as much affected by digestion as that in the vial; there was little or no difference in their appearance. Returned it again.

"At 1 o'clock, P. M., I drew out the string; but the meat was all completely digested, and gone.

"The effect of the gastric juice on the piece of meat, suspended in the stomach, was exactly similar to that in the vial, only more rapid after the first half hour, and sooner completed. Digestion commenced on, and was confined to, the surface entirely, in both situations. Agitation accelerated the solution in the vial, by removing the coat that was digested on the surface; enveloping the remainder of the meat in the gastric fluid; and giving this fluid access to the undigested portions."—*Experiments and Observations on the Gastric Juice, and the Physiology of Digestion. By W. Beaumont, M. D., Surgeon in the U. S. Army. Boston.* 1834.

CHAPTER IX.

SECTION II.

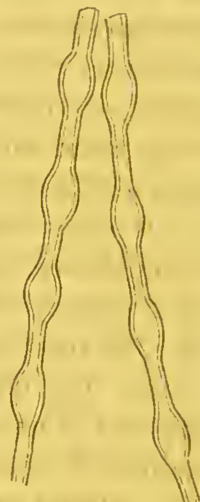
An important contribution to anatomy has recently been made by Professor Ehrenberg: it is to be found in the Transactions of the Berlin Academy for 1834, printed in February 1836.

The medullary substance of the nervous system is finally

determined to be tubular, the character of the tubes varying in different parts.

The cortical substance appears to consist of a finely-granular soft substance, in which numerous larger corpuscles are disposed. The large corpuscles are free; they are resoluble into smaller ones: the finer granules appear strung on filaments like beads.

The nature of these seeming strings of beads is explained in the first of the following propositions, which are a summary of Professor Ehrenberg's discoveries.



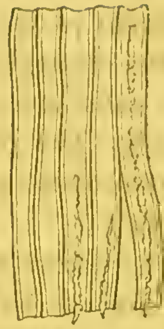
1. The substance of the brain consists neither of globules, nor of simple filaments, but of tubes from $\frac{1}{96}$ to $\frac{1}{3000}$ of a line in diameter, ampullated, laid parallel, and not branching. These tubes, becoming coarser, converge towards the base of the brain and the ventricles. They are individually not connected by cellular tissue: they are produced to form the spinal cord. Ehrenberg calls these tubes articulated tubes. *Ampullated nerve tubes* is perhaps a better designation.

3. The spinal cord of man and vertebral animals consists of similar ampullated tubes: they are disposed parallel to each other: the larger are external, the finer internal. The external larger tubes are continuous with the cylindrical tubes, of which the spinal nerves consist.

4. The first, second, and auditory nerves, consist of similar ampullated nerve tubes. The tubes are not all of the same size: they are largest, and the ampullæ are proportionately less, in the auditory nerve. In the olfactory, the ampullæ are most numerous and irregular. These three nerves are called, by Ehrenberg, articulated nerves. The sympathetic nerve combines ampullated nerve tubes with cylindrical nerve tubes.

5. In the ampullated tubes of the brain, spinal cord, and articulated nerves, there is found a transparent glutinous liquid, the *liquor nerveus:* it is not demonstrably granular. A visible motion of this fluid is not ascertainable; but its slow propulsion is probable.

6. All the other nervous trunks consist not of ampullated tubes, but are made up of cylindrical tubes, something coarser



than the others, grouped in fasciculi surrounded with membrane. They are continuous with the ampullated tubes of the spinal cord and brain. The change of figure is immediate and sudden, and takes place conjointly with the assumption of a cellular tissue. These cylindrical tubes, which present the extremes of largeness and fineness in invertebral animals, are found in them from $\frac{1}{48}$ to $\frac{1}{1000}$ of a line in diameter. In vertebral animals, they are commonly from $\frac{1}{120}$ to $\frac{1}{240}$ of a line in diameter. They contain a peculiar granular, as it were coagulated, medullary pith, which may be squeezed out of them, leaving them empty. Ehrenberg calls these nerve tubes. A better term perhaps would be *cylindrical nerve tubes.*

7. Nervous substance consists therefore of two constituents; of ampullated or articulated tubes containing liquor nerveus, and of cylindrical tubes containing a pith.

8. The brain contains none of this pith.

9, 10. The double cord of articulated animals is principally composed of nerve tubes, containing a very small proportion of ampullated tubes with blood particles.

12. Almost all the extremities of the nervous system (least so, however, in the ear) are involved in a dense vascular network, and contain detached and scattered granules of a larger size, the magnitude of which bears a relation to the magnitude of the blood particles.

12. The structure of the retina has hitherto been described erroneously. The granular medullary layer, which forms the anterior surface of the retina, is clothed and penetrated by a network of vessels from the central artery: behind it lies the expansion of the optic nerve, which consists of ampullated canals, and is divisible into a peripheral cortical, and a central medullary substance. Some scattered corpuscles and plates are laid between them. The connection of the latter with the ampullated tubes of the nerves is not yet ascertained.

The blood particles consist in vertebral animals, as Hewson observed, of a middle colourless corpuscle, resembling the chyle corpuscles, and a red homogeneous envelope. To invest the lymph corpuscles with that envelope, appears to be the object of the vascular and respiratory systems. In no vertebral ani-

mals, but in many — perhaps in most — invertebral animals, the envelope of the blood particles is wanting *. The nuclei of the blood particles consist of still smaller sphericles; which in mammalia are $\frac{1}{3600}$ of a line in diameter, but in invertebrals are smaller. These three elements of the blood are best shown in amphibia, where the particles are larger, and the envelope of the nuclei is at once larger in proportion, and separates in water much faster than the nucleus decomposes. The number of blood particles is directly proportionate to the number of ampullated tubes in the nervous system of animals.

At the terminations of the nervous structure, colourless corpuscles of larger size make their appearance. These have been already spoken of in connection with the cortical substance of the brain. They are found again in the retina. In the brain and in the retina of frogs, Ehrenberg observed particles of blood (arranged like beads upon a string) much smaller and paler than elsewhere: they had lost part of their envelope. He conjectures, that possibly the free corpuscles in the endings of the nervous substance may be nuclei of blood particles.

In some of the terminations of nerves prismatic corpuscles are met with. Such are found in the retinæ of frogs and fish; while globular corpuscles are found in the Schneiderian membrane.

The smallest visible anastomosing capillaries are considerably larger than the ampullated nerve tubes, among which they are distributed. A great many branches of blood-vessels appear to have free ends, at least they do not anastomose; but the ends themselves have as yet eluded observation.

The ganglions present some varieties of structure. All have this in common, that they contain ampullated nerve tubes; which either, as in the commissure of the optic tracts, form the whole structure; or, as in the ganglions of the sympathetic, are mixed with cylindrical nerve tubes and corpuscles such as are found in the retina, and in the cineritious substance of the brain. The last fact favours greatly the old idea

* Thus it appears, that the central part of a blood particle, which to Dr. Young appeared a shallow depression on a flat surface, is a nucleus or interior corpuscle. This appearance, which I have repeatedly verified, may arise from the nucleus shrinking in drying. Of course it is now to be presumed, that the seeming central depression, which I observed in pus particles, is a nucleus like that of blood particles.

[which Magendie's experiment of destroying the Gasserian ganglion physiologically confirms], that the ganglions are little brains, or *originators*. In the ganglions of the spinal nerves in birds, Ehrenberg observed large, irregular, globular particles, more like the molecules of the thymus gland. In the ganglions, the ampullated nerve tubes become larger, but not so large as the cylindrical nerve tubes.

The observations of Professor Ehrenberg were made with a compound microscope. The power which he found it most convenient to use, as allowing of more light than higher powers, magnified from 350 to 360 diameters. The nervous substance should be examined as recently as possible. "To make sections of the brain," he observes, "I use a double-edged, thin, broad, and pointed knife; and cut by drawing it. The thinnest slice of brain so cut off, I place upon a small plate of glass with a needle or the point of a knife. Then, by a vertical section, I cut off from its edge, where thinnest and most perfect, the narrowest strip I can obtain. This fine strip I immediately examine with the microscope as it is, without using water or pressure. I then lay upon it a small plate of glass, about five lines in breadth, and a third of a line in thickness." By this means equable pressure may be made upon the fragment, so as to spread it out to a greater breadth. The fragment is then in a convenient state for further examination. A drop of water upon the fragment does not dissolve it, and sometimes produces a useful view. An horizontal motion of the upper piece of glass on the lower completely deranges the structure. When irregular corpuscles and globules make their appearance, the observer may conclude that he has used too much pressure, and broken down the natural structure.

CHAPTER IX.

SECTION VI.

In page 260, I have attributed to Mr. Newport more than he claims as his own in his valuable contributions to the Philosophical Transactions. The existence of the ganglionic or periphericar, and ganglionless or axial portion of the double cord

of articulated animals, was made out by Müller; and the specific offices of the two were conjectured (and it still remains a conjecture, though a felicitous and highly probable one) by Dr. Grant.

The two smaller fasciculi, superimposed upon the motor fasciculi, have been described by Mr. Newport alone. They are not the analogues of the sympathetic. The visceral nerves, including the sympathetic, have been described by Swammerdam, Lyonnet, Cuvier, and others.

The argument in page 260 is therefore right, although the illustrations advanced are in some points erroneous.

CHAPTER X.

SECTION VI.

The sense of touch, it is stated in the text, page 320, has its finest development at the extremities of the fingers, the lips, the tongue.

Professor Weber has published some interesting experiments on the differences observable in the accuracy of this sense on different surfaces. Where touch is acutest, the contact of two points (*e. g.* those of a pair of compasses) is felt to be double, when they touch two closely-adjoining points of the surface. Elsewhere, to produce a double impression, the two points applied must be more remote. The following table gives the *nearness* at which, on different surfaces, two simultaneous contacts are first distinguishable to be two.

	Lines.
The tip of the tongue	$\frac{1}{2}$
The tip of the finger	1
The red surface of the lips	2
The anterior surface of the second phalanx	2
The back of the third phalanx	3
The tip of the nose	3
The back of the tongue	4
The part of the lips not red	4
The point of the great toe	5
The back of the second phalanx of the finger	5
The middle of the palm of the hand	5

	Lines.
The hard palate	6
The zygoma	7
The back of the knuckles of the hand	8
The inner surface of the lips	9
The forehead	10
The occiput	12
The back of the hand	14
The neck below the chin	15
The knee-pan and the neighbouring surface	16
The sacrum	18
The breast-bone	18
The lumbar vertebræ	24
The middle of the upper arm	20
The middle of the thigh	30

If the points of a pair of compasses are applied to the cheek immediately before the ear, one above the other, and the instrument is then drawn with its points in contact with the skin to the angle of the mouth, the compasses *are felt* as if they were progressively opening. Upon the limbs, a smaller transverse distance is appreciable than a longitudinal one.

Professor Weber made parallel observations as to weights, the part experimented on *being passive;* and found that a lighter weight, on a part with higher sensibility to contact, seemed as heavy as a heavier weight on a duller surface.

In respect to temperature, he found that the quantity of surface affected influenced the impression. If one *finger* is introduced into a vessel of warm water, and the other *hand* is introduced into another a little less warm, the latter *seems* to be immersed in the warmer fluid.—*Archiven für Anatomie, &c. von Dr. Johannes Müller.* 1835. Heft. i, p. 152.

CHAPTER X.

SECTION IX.

It appears satisfactorily proved, that the acuteness of perception which birds evince, whether in discovering food, or in tracing their way home, is through sight. To establish the first of these points, I shall quote some observations by Audubon.

"My first experiment," says Audubon, "was as follows: — I procured a skin of our common deer, entire to the hoofs, and stuffed it carefully with dried grass until filled rather above the natural size — suffered the whole to become perfectly dry, and as hard as leather — took it to the middle of a large open field — laid it down on its back with the legs up and apart, as if the animal was dead and putrid. I then retired about a hundred yards, and in the lapse of some minutes, a vulture, coursing round the field tolerably high, espied the skin, sailed directly towards it, and alighted within a few yards of it. I ran immediately, covered by a large tree, until within about forty yards, and from that place could spy the bird with ease. He approached the skin, looked at it with apparent suspicion, jumped on it, raised his tail, and voided freely (as you well know all birds of prey in a wild state generally do before feeding), — then approaching the eyes, that were here solid globes of hard, dried, and painted clay, attacked first one and then the other, with, however, no farther advantage than that of disarranging them. This part was abandoned; the bird walked to the other extremity of the pretended animal, and there, with much exertion, tore the stitches apart, until much fodder and hay was pulled out; but no flesh could the bird find or smell: he was intent on discovering some where none existed; and, after reiterated efforts, all useless, he took flight and coursed about the field, when, suddenly wheeling round and alighting, I saw him kill a small garter-snake, and swallow it in an instant. The vulture rose again, sailed about, and passed several times quite low over the stuffed deer-skin, as if loth to abandon so good-looking a prey. Judge

of my feelings, when I plainly saw that the vulture, which could not discover, through its extraordinary sense of smell, that any flesh, either fresh or putrid, existed about that skin, could at a glance see a snake, scarcely as thick as a man's finger, alive, and destitute of odour, hundreds of yards distant. I concluded, that, at all events, his ocular powers were much better than his sense of smell.

"Second experiment.—I had a large dead hog hauled some distance from the house, and put into a ravine, about twenty feet deeper than the surface of the earth around it, narrow and winding much, filled with briars and high cane. In this I made the Negroes conceal the hog, by binding cane over it, until I thought it would puzzle either buzzards, carrion-crows, or any other birds to see it, and left it for two days. This was early in the month of July, when, in this latitude, a dead body becomes putrid and extremely fœtid in a short time. I saw from time to time many vultures, in search of food, sail over the field and ravine in all directions; but none discovered the carcass, although during this time several dogs had visited it, and fed plentifully on it. I tried to go near it, but the smell was so insufferable when within thirty yards, that I abandoned it, and the remnants were entirely destroyed at last through natural decay. I then took a young pig, put a knife through its neck, and made it bleed on the earth and grass about the same place; and, having covered it closely with leaves, also watched the result. The vultures saw the fresh blood, alighted about it, followed it down into the ravine, discovered by the blood the pig, and devoured it, when yet quite fresh, within my sight."

The following account of the carrier pigeon, which shows sufficiently on what sense it relies, I gathered by inquiries from a very intelligent person who deals in birds.

Carrier pigeons, of which the Dutch is the best breed, are thus trained:—At eight to ten weeks of age they begin to *run*, or to make flights of from four to five hours from the nest. They are then strong enough on the wing to commence their education. The pigeon to be trained is first taken no greater distance than a mile from home, and tossed into the air: when, after flying round and round, and rising some height into the air, it wings its way back. This lesson is repeated five or six times in as many days. The bird is then carried to the distance

of two miles, and tossed. This lesson is repeated twice. The bird is next carried three miles, and tossed; and this lesson is likewise repeated two or three times. The bird is then carried six miles, and then twelve, then twenty-four, then forty-eight, then ninety-six, and so on, in a geometrical ratio. Each of these lessons is given once only. The longest flight that a carrier-pigeon has been known to make is 800 miles. In so long a flight, the bird is supposed to pitch at night and roost, renewing its flight the following day.

When a trained carrier-pigeon is tossed, after making one or more circles it rises in a rapid spiral to an enormous height, before it takes its departure, and at that height it is supposed to pursue its journey. The speed of the Antwerp birds, which are lighter and more finely made than the English breed, is supposed to be a mile a minute. They are more extensively used than is supposed in financial transactions: one eminent speculator at Antwerp keeps 1,200 pigeons. The value of a pair of well-trained Dutch birds is five pounds.

The feats of these birds, when they are used for moderate distances, are certainly effected directly through vision: the birds *see* their way. They rise sufficiently high to command a view of distant known objects, which their fine sight enables them to recognize at immense distances. If their sight is baffled, they lose their way; so, if they set off in foggy weather, they are sometimes two, three, or four days, or even a week, in making a passage which would otherwise occupy a few hours only: sometimes, under these circumstances, they never reach home.

It is evident that at greater distances (on the rule of training described already) there must be something more than direct vision to guide them; they must rely upon recollected direction as well as upon the sight of recollected objects; or they must employ some general ideas of direction, in which, perhaps, the position of the sun may help them, in addition to the sight of known terrestrial objects.

They are taught one lesson only, and can make but one journey; that is to say, they can only find their way home along the road which they have studied.

CHAPTER XII.

SECTION I.

Professor Wagner, of Erlangen, has published an account of the generation of the spermatic animalculæ, or cercariæ seminis, in birds.

There are three elements, he states, in the seminal secretion of all animals, — a homogeneous liquid, corpuscles of different form and magnitude, and the seminal animalculæ.

In the contents of the testis of the yellowhammer, in winter, there is found a small quantity of liquid containing corpuscles, from $\frac{1}{250}$ to $\frac{1}{200}$ of a line in diameter. In the spring these corpuscles present themselves under various appearances. Among them are groups of the cercariæ: the latter are contained in thin bladders, round or oval: the smallest $\frac{1}{50}$ of a line in diameter; others $\frac{1}{20}$. The cercariæ are individually fine threads with a corkscrew extremity: they are disposed parallel to each, and are folded at their middle, the straight end upon the corkscrew end.

Professor Wagner shows reason for supposing the corpuscles to be the source of the groups of cercariæ. They are seen to be filled with little molecules. These are probably rudiments of cercariæ. The corpuscles enlarge from $\frac{1}{400}$ to $\frac{1}{60}$ of a line in diameter. The largest observed contain molecules, which have a disposition to assume a linear form. In the vas deferens these intermediate ones are not found; the cercariæ only and the minuter corpuscles appear there.

There is great interest in these observations. They show that the cercaria is an animal, growing by a process of gradual formation like the animals which produce it. The obvious application of the fact, is to elucidate the production of other entozoa. The latter are probably natural formations of *other* organs.—*Archiv. fur Anatomie, von D. Müller,* 1836, p. 225.

CHAPTER IX.

SECTIONS II, III, IV.

Under the name of "reflex function of the spinal cord," Dr. M. Hall has investigated a principle, which was explicitly laid down in my Anatomical Commentaries, *published in* 1823 [Part II, page 138], in the following words :—

"An influence may be propagated from the sentient nerves of a part to their correspondent nerves of motion, *through the intervention of that part alone of the nervous centre, to which they are mutually attached.* Thus in vertebral animals, in which alone the fact is questionable, when the spinal cord has been divided in two places, an injury of the skin of either region is followed by a distinct muscular action in that part. Again: if the brain is quickly removed from the head of a pigeon, leaving only the crura cerebri, together with the tubercles and the second and third nerves, on pinching the second nerve, the iris contracts."

The same view and the same facts, carefully distinguished from the agency of sensation and volition, have been put forward in the former editions (as in the present) of my Outlines of Physiology.

The facts, which Dr. M. Hall has added to the knowledge existing on this subject long before he wrote, are, that after the spinal cord of a turtle has been divided, its sphincter ani continues to act; and that in a frog made tetanic by strychnine, division of the cord, in the back and in the neck, leaves each part tetanic.

These facts, valuable in themselves, are likewise good exemplifications of the principle above laid down. But their excellence, as examples, does not authorize Dr. M. Hall *to affirm, in* 1833, that the independent power of the spinal cord "had never been accurately distinguished from sensation and volition;" which he asserts in a paper in the Philosophical Transactions for that year, wherein he claims that distinction, and the principle it involves, as a discovery.

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UNDER the name
Dr. M. Hall h-